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Developing and Utilizing an Euler Computational Method for Predicting the Airframe/Propulsion Effects for an Aft-Mounted Turboprop Transport

Volume II: User Guide

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TABLE OF CONTENTS

1.0 INTRODUCTION

This manual describes how to use the program PFE889 (Vol. I, Ref. 1) to analyze the flow about a transport aircraft configuration. PFE889 accepts a description of the configuration surfaces and flow conditions, generates a three dimensional field grid about the configuration, solves the Euler equations on this grid, and provides for display of relevant flow quantities. The configuration must consist of a fuselage, and wing, and can optionally include an aft nacelle with or without propfan, a strut or conventional horizontal tail, or a high horizontal tail mounted on top of the vertical stabilizer. Computed flow properties such as pressure, density, and velocity can be examined on the configuration surface or on a specified surface within the flowfield, and streamlines can also be displayed. A local grid embedding capability allows users to examine areas of particular interest with greater resolution than is provided by the overall grid.

This description pertains to use of the program on a Cray-2 computer running the UNICOS operating system. However, PFE889 is not strongly bound to that environment, and in fact was initially developed on a Cray X-MP under COS. A discussion of its conversion to UNICOS is contained in Appendix A. A flow chart for Euler flow solver is given in Appendix B

The separate computer codes which make up PFE889 perform four main functions: grid generation, numerical solution of the Euler equations, locally embedding a refined grid, and computing streamlines of the flow. Input and output for each function is described in the next two sections.

2.0 OPERATION OF THE PROGRAM

Input preparation, commonly called preprocessing, for the Euler analysis program consists of four steps: surface geometry generation, computing the volume grid, smoothing this grid, and checking the grid for degenerate regions. PFE889 does not provide surface geometry generation capability, so users must rely on other means to prepare the discrete description of the aircraft. Program system BEGRID reads this description, along with other data, from file "grd1inp", generates the volume grid required by the Euler code, and writes it in binary format to file "eulergrid". BEGRID requires two other input files: "grd2inp" and "components". All three input files are discussed in subsection 2.2. BEGRID also produces a supplementary output file called "surfacegrid", which contains a formatted description of the computed grid on the configuration surface. It can be used as input to PLOT3D, or other graphics utilities, to examine grid quality.

Program BBEAM2, which carries out the numerical solution of the Euler equations, reads the binary file "eulergrid" and a user prepared input file called "flowinp". It produces two main output files, "ffsinglb" and "surfpress", which contain the flowfield solution and surface pressures, respectively. These files can be used as input to graphical post processing programs, including the streamline visualization program, and also to the grid embedding procedure for more accurate resolution of certain regions of the flowfield.

2.1 PROGRAM FUNCTIONS AND LINKAGE

BEGRID actually consists of four codes which are run consecutively by a Unix script, such as that given in Appendix C. The first code, BEGRID1, reads the configuration geometry file and produces three intermediate files, "wing", "fuslag", and "nacelle". BEGRID2 reads these along with "grd2inp" and generates the volume grid. Smoothing the grid along block interfaces is done in BEGRID3. Finally BEGRID4 checks the grid for negative volume cells and slightly reformats the binary grid file. Each of these codes also produces an output file which records its execution history. Examining these output files, named "beg1.out", "beg2.out", "beg3.out", and "beg4.out", may help to diagnose any problems that arise in generating the grid. Before proceeding with the flow solution, users should visually examine the completed grid and must check file "beg4.out" for negative volume cells.

BBEAM2 is also run from within a Unix script, as shown in Appendix C. If desired, it can be run in increments, each time restarting with the most recently computed flowfield. BBEAM2 can also use the solution from an identical geometry but different freestream conditions as a starting point. In both these cases, BBEAM2 needs the computed flowfield binary file "ffslnglb", in addition to the grid file, as input. The "ffslnglb" file must be either renamed to "fort.10" or assigned an alias of "fort.10" when used as an input file for BBEAM2.

Figure 1 summarizes the execution sequence and input-output of the PFE889 codes used to compute the flowfield's global solution.

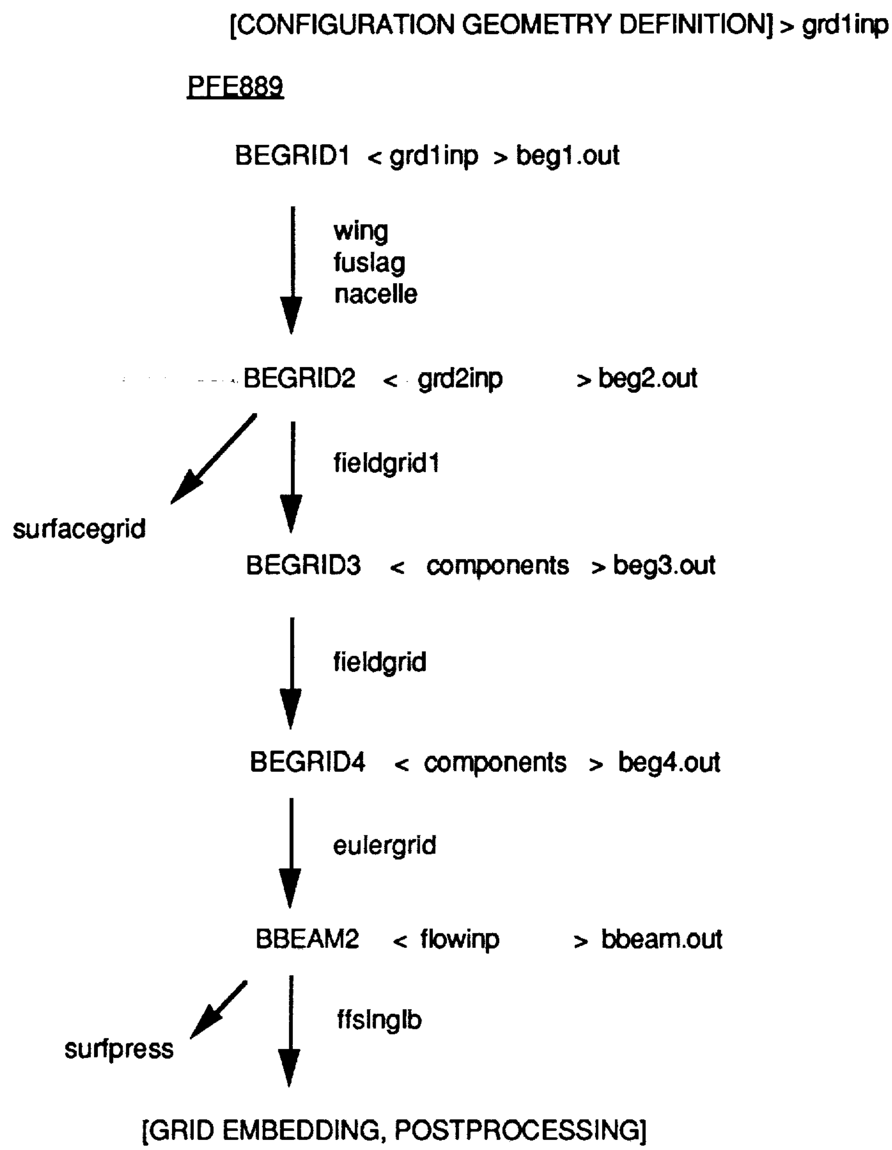


Figure 1. Aerodynamic analysis using PFE889. Executable programs are shown in upper case, files are shown in lower case. The "<" and ">" symbols denote input and output respectively, in the style of a Unix command line.

2.2 INPUT FILE DESCRIPTIONS FOR OUT-OF-CORE SOLUTION

2.2.1 PREPARATION OF INPUT FILE grd1inp

This file is required as an input to the grid generation preprocessor program BEGRID1. grd1inp contains general inputs, geometric curves describing the fuselage, and airfoil sections for the wing, strut, vertical tail and horizontal tail. Although the entire configuration can be described here, the flags in the flow solver input may be used to ignore ("flow through") some gridded components. The file also contains the geometric curves for the nacelle. These inputs are briefly described below:

Note: The global (X,Y,Z) coordinates are roughly aligned with the streamwise, the vertical tail spanwise, and the wing spanwise directions, respectively. The aircraft is assumed symmetric with respect to the Z=0 plane. In the rest of this manual, the positive Z is referred as the right side.

- **General Input**

This data includes such information as the desired size of the grid (number of cells to be constructed in each direction of the computational grid), and parameters that tell the program which components are present.

- **Fuselage Definition**

These are basically constant X cuts on the fuselage. The point description for each of these curves includes the X coordinate where the cut is located, and a set of (Y,Z) coordinate pairs.

- **Wing Definition**

The wing section curves are airfoil sections located at consecutive spanwise stations. Airfoil section coordinates are non-dimensionalized by local chord length, with the leading edge coordinate set to (0,0). Global coordinates of the leading edge, the physical chord of the section, and certain scaling factors are also included as input.

- **Nacelle (Aft-Mounted) Definition**

Nacelle sections are circumfrential cuts similar to fuselage sections. Sections cuts on each side of the nacelle are input separately. A cut is not required to have constant X coordinate.

- **Strut (or Conventional Horizontal Tail) Definition**

Strut sections are similar to wing sections. Section cuts on the upper and lower surfaces of the strut are input separately. Strut sections are described in the global coordinate system. Certain strut sections, such as the strut-fuselage intersection and the strut-nacelle intersections, will most likely be non-planar, and should be input accordingly.

- **Vertical Tail Definition**

Vertical tail section curves are symmetric airfoil sections located at various spanwise stations. Only one half of the section needs to be input, and points are specified in the global coordinate system.

The root section should be the vertical tail-fuselage intersection and the tip section may describe the vertical tail high-horizontal tail intersection.

- **High Horizontal Tail Definition**

Horizontal tail sections are similar to the strut sections. The upper and lower surfaces of a section cut are input separately. The section describing the high horizontal tail-vertical tail intersection will generally be non-planar.

General Input

Card	Column	Code	Format	Explanation
1	1-80	TITLE	A80	An 80-column title to be placed on the output of program BEGR1D1.
2	1-80		1X	Header card. Header cards are essentially dummy cards provided for identification of the data in the following cards. Typically the fields in the header cards should include the generic names of the variables to be included in the field in the following card (s). The header cards are read in by format (1x), which means that they may contain any legal characters including blanks

A typical header card is shown below:

FNX FNY FNZ

The header card is provided for easy identification of the input variables in the input file without having to look into Fortran code in the program. FNX, FNY, etc. in the above line are the names of the variables to be read on the following card. It is not imperative that the header card be typed exactly since it is not read in by any rigid format in the program.

Card	Column	Code	Format	Explanation
3	1-10	FNX	F10.0	Number of grid cells on the wing surface in the I direction of the computational domain. In the physical domain this corresponds to the number of cells on the upper and lower surfaces of the wing in the chordwise direction of the wing (global X-direction). Note: FNX is not the total number of cells in the I direction. See input TNX. Typical value = 80.0
	11-20	FNY	F10.0	Total number of grid cells in the J direction of the computational domain. In the physical domain this corresponds to the number of cells in the direction normal to both the wing chord and span (global Y direction). Typical value = 36.0

	21-30	FNZ	F10.0	Number of grid cells on the wing surface in the K direction of the computational domain. In the physical domain, this corresponds to the number of cells on the wing in the spanwise direction (global Z direction). Typical value = 24.0
4	1-80		1X	Header Card
5	1-10	FSPAN	F10.0	Parameter specifying in the spanwise distribution of the wing surface grid. =0 If the spanwise wing surface grid stations are to be placed at equal intervals. =1 If the spanwise wing surface grid stations are to be calculated using the cosine rule. Requires parameters FSB, FST. =2 If the spanwise surface grid stations for K=1 to FKTIPT are to be placed at equal intervals. In this mode the user must specify the number of evenly spaced spanwise grids (FKTIPT) and the spanwise location of the K=FKTIPT grid surface (ZSPAN). Grid surfaces outboard of FKTIPT will be smoothly distributed. This mode allows users to match evenly spaced grid surfaces on the wing to those on the tail, strut, or nacelle.
	11-20	FSB	F10.0	Used only if FSPAN=1.0. Control parameter for the spanwise grid lines near the root of the wing. Value must be between 0.0 and 1.0; 0.0 gives uniform spacing and 1.0 gives a cosine (denser) distribution near root.
	21-30	FST	F10.0	Used only if FSPAN=1.0. Control parameter for the spanwise distribution of the grid lines near the tip of the wing. Value must be between 0.0 and 1.0; 0.0 gives uniform spacing and 1.0 gives a cosine (denser) distribution near tip.
	31-40	ZSPAN	F10.0	Used only if FSPAN=2.0. Spanwise location of the wing surface grid at K=FKTIPT.
	41-50	FKTIPT	F10.0	Used only if FSPAN=2.0. Number of uniformly spaced spanwise grids.
6	1-80		1X	Header Card
7	1-10	TNX	F10.0	Total number of cells in the I direction of the computational domain. In the physical domain TNX equals twice the number of cells in the X-direction along the wing, the wake, and the downstream farfield. Typical value = 240.0
	11-20	TNZ	F10.0	Total number of cells in K direction of the computational domain. Includes the wing surface plus an extension to the outer boundary. In the physical domain this corresponds to the total number of cells in the wing spanwise direction (Z-direction). Typical value = 32.0

7	21-30	NW1	F10.0	Number of cells between the T. E. of the wing and the L. E. of the strut along the wake. Typical value = 16.0
8	1-80		1X	Header Card
9	1-10	FHTAIL	F10.0	Parameter to indicate whether the strut (or conventional horizontal tail) is present in the generated grid. FHTAIL = FTAIL in page 18. Note: Strut (tail) data must always be input. =1.0 Grid will be generated with the strut. =0.0 Grid will be generated without strut. In this mode the strut is collapsed to a slit of zero thickness.
	11-20	FNACEL	F10.0	Parameter specifying the presence of the aft-mounted nacelle. FNACEL = FIUBE in page 16 and = FUBE in page 18. =1.0 If the aft-mounted nacelle is present. =0.0 If the aft-mounted nacelle is absent
	21-30	FHVTAIL	F10.0	Parameter specifying the presence of the H.V. tail (the horizontal tail which is located on the top of the vertical tail). FHVTAIL = HVTAIL in page 18. =1.0 If the H.V. tail is present. =0.0 If the H.V. tail is absent.

Fuselage Definition

Card	Column	Code	Format	Explanation
F1	1-80		1X	Header Card
F2	1-10	FIFUS	F10.0	Number of input curves to describe the fuselage geometry. Note: Each fuselage section curve consists of a number of points in a constant X plane. These curves must be single valued in Z coordinate with respect to the Y coordinate. The set of cards F3 - F6 must be repeated FIFUS times. Typical value = 31.0
F3	1-80		1X	Header Card
F4	1-10	XF	F10.0	X coordinate at which the curve is located.
	11-20	FN	F10.0	Number of points on the curve. Typical value = 19.0
F5	1-80		1X	Header Card

F6	1-10	YP	F10.0	Y coordinate of a point on the curve.
	11-20	ZP	F10.0	Z coordinate of a point on the curve.
				Note: The points on the curve should be ordered from the crown to keel.

Wing Definition

Each wing section is input in a nondimensionalized form via a set of X/C, Y/C values referred to a coordinate system attached to the leading edge of the section. The upper and lower surface of the section are input separately. Wing sections are positioned by specifying the global coordinates of their leading edge point, along with two scaling factors and a pitching angle.

Card	Column	Code	Format	Explanation
W1	1-80		1X	Header Card
W2	1-10	FNS	F10.0	Number of wing sections to be input. Typical value = 19.0
	11-20	SWEEP	F10.0	Leading edge sweep angle in degrees.
	21-30	DIHED	F10.0	Dihedral angle in degrees.
				Note: There must be FNS sets of cards W3-W10.
W3	1-80			Header Card
W4	1-10	ZLE	F10.0	Z coordinate of the leading edge of the section.
	11-20	XL	F10.0	X coordinate of the leading edge of the section.
	21-30	YL	F10.0	Y coordinate of the leading edge of the section.
	31-40	CHORD	F10.0	Chord length of the section being input.
	41-50	THICK	F10.0	Thickness scaling factor for the section. The y/c coordinates are multiplied by this factor to calculate the airfoil shape that is actually used to generate the surface grid. We do not recommend the use of this parameter. Set its value to 1.0.
W4	51-60	AL	F10.0	Pitching angle of the section. The airfoil is always pitched about its leading edge.
				Note: Do not use this input unless you are familiar with the effect on such a rotation on the computed grid. Normally set AL=0.0

	61-70	FSEC	F10.0	Parameter to indicate whether the previous section is to be repeated. =0.0 previous section is to be used. =1.0 new section on cards W5-W10 is expected. Note: Cards W5-W10 are to be provided only if FSEC=1.0
W5	1-80		1X	Header Card
W6	1-10	YSYM	F10.0	Parameter indicating the symmetry of the section. =0.0 if the section is not symmetric. Both the upper and lower section curves are to be input. =1.0 if the section is symmetric. Only the upper section curve may be input. The lower section curve is derived by inverting the upper section curve about the origin and the X/C axis.
	11-20	FNU	F10.0	Number of points on the upper section curve. Typical value = 51.0
	21-30	FNL	F10.0	Number of points on the lower section curve. Note: FNL may be different from FNU only if YSYM = 0. If YSYM = 1, then FNU and FNL must be equal. Typical value = 51.0
W7	1-80		1X	Header Card Note: Card W8 must be repeated FNU times.
W8	1-10	XPU	F10.0	X/C coordinate of the point on the upper section curve. A typical X/C distribution for a transport wing section for both the upper and lower surfaces can be found in Appendix D.1.
	11-20	YPU	F10.0	Y/C coordinate of the point.
W9	1-80		1X	Header Card Note: Card W10 must be repeated FNL times.
W10	1-10	XPL	F10.0	X/C coordinate of the point on the lower section curve.
	11-20	YPL	F10.0	Y/C coordinate of the point.

Nacelle (Aft-Mounted) Definition

A nacelle is described by a series of circumfrential cuts from upstream to downstream. Each cut consists of an inboard segment followed by an outboard segment . Both of these sets of points are ordered from crown to keel.

Once the nacelle geometry is read in, the program will automatically generate plume geometry by extending the nacelle trailing edge to the downstream farfield.

Card	Column	Code	Format	Explanation
N1	1-80		1X	Comment card which identifies the following nacelle data.
N2	1-80		1X	Header Card
N3	1-10	FNOUT	F10.0	Number of grid points to be constructed on each half section (inboard or outboard) of the nacelle. Note: Each output curve will lie on a streamwise cut plane. Typical value = 40.0
	11-20	AA1C	F10.0	Specified grid spacing at the crown of the nacelle to control the circumferential grid distribution. This value must be normalized by the circumferential arc-length between the crown and keel of the nacelle section. Recommended value = 0.02
	21-30	BB1C	F10.0	Specified grid spacing at the keel of the nacelle to control the circumferential grid distribution. This value must be normalized by the circumferential arc length between the crown and keel of the nacelle section. Recommended value = 0.02
	31-40	FKCUT	F10.0	Number of sections to be constructed on the nacelle at increasing X stations. Typical value = 45.0
	41-50	AA1S	F10.0	Specified grid spacing at the leading edge of the nacelle to control the streamwise grid distributions. This value must be normalized by the arc-length along the crown line between the L. E. and T. E. of the nacelle. Recommended value = 0.01
	51-60	BB1S	F10.0	Specified grid spacing at the trailing edge of the nacelle to control the streamwise grid distributions. This value must be normalized by the arc length along the crown line between the L.E. and T.E. of the nacelle. Recommended value = 0.05
N4	1-10	NSNAC	I10	Number of nacelle input curves to describe the nacelle inboard and outboard geometries. Note: The set of cards N5-N8 must be repeated NSNAC/2 times. Typical value = 62.0
N5	1-10	NNCIB	I10	Number of points on the nacelle inboard curve. Note: Card N6 must be repeated NNCIB times for each set of data. Typical value = 120.0

N6	1-15	XNIB	F15.7	X-coord. of a point on the nacelle inboard curve.
	16-30	ZNIB	F15.7	Z-coord. of the point
	31-45	YNIB	F15.7	Y-coord. of the point.
N7	1-10	NNCOB	I10	Number of points on the nacelle outboard curve. Note: Card N8 must be repeated NNCOB times for each set of data.
N8	1-15	XNOB	F15.7	X-coord. of a point on the nacelle outboard curve.
	16-30	ZNOB	F15.7	Z-coord. of the point.
	31-45	YNOB	F15.7	Y-coord. of the point.

Strut (or Conventional Horizontial Tail) Definition.

The strut (tail) is described by a series of section curves ordered from root to tip. Each strut section curve consists of an upper surface segment followed by a lower surface segment. Both of these sets of points are ordered from L. E. to T. E.

Card	Column	Code	Format	Explanation
S1	1-80		1X	Comment card which identifies the following strut (tail) data.
S2	1-80		1X	Header Card.
S3	1-10	FNOUT	F10.0	Number of grid points to be constructed on a section curve (including upper and lower surfaces) of the strut on a spanwise cut plane. Typical value = 65.0
	11-20	AA1C	F10.0	Grid spacing specified at the L. E. of the strut to control the grid distribution in the chordwise (X) direction. This value must be normalized by the chord of the strut. Recommended value = 0.03
S3	21-30	BB1C	F10.0	Grid spacing specified at the T. E. of the strut to control the grid distribution in the chordwise (X) direction. This value must be normalized by the chord of the strut. Recommended value = 0.05
	31-40	FKCUT	F10.0	Number of sections to be constructed on the strut in the spanwise (Z) direction. Typical value = 9.0
	41-50	AA1S	F10.0	Grid spacing specified at the root of the strut to control the grid distribution in the spanwise (Z) direction. This value must be normalized by the span of the strut. Recommended value = 0.10

Card	Column	Code	Format	Explanation
	51-60	BB1S	F10.0	Grid spacing specified at the tip of the strut to control the grid distribution in the spanwise (Z) direction. This value must be normalized by the span of the strut. Recommended value = 0.10
S4	1-10	NSSTR	I10	Number of strut input section curves to describe the strut upper and lower surface geometries. Note: The set of cards S5-S8 must be repeated NSSTR/2 times. Typical value = 6.0
S5	1-10	NSTUP	I10	Number of points on the strut upper section curve. Note: Card S6 must be repeated NSTUP times for each set of data. Typical value = 52.0
S6	1-15	XSUP	F15.7	X-coord. of a point on the strut's upper section curve.
	16-30	ZSUP	F15.7	Z-coord. of the point.
	31-45	YSUP	F15.7	Y-coord. of the point.
S7	1-10	NSTLO	I10	Number of points on the strut lower section curve. Note: Card S8 must be repeated NSTLO times for each set of data. Typical value = 52.0
S8	1-15	XSLO	F15.7	X-coord. of a point on a strut lower section curve.
	16-30	ZSLO	F15.7	Z-coord. of the point.
	31-45	YSLO	F15.7	Y-coord. of the point.

Vertical Tail Definition

The vertical tail is described by a series of section curves, each at a constant span location, ordered from base to tip. Since the tail is symmetric, section curves consist of points on one side only, ordered from leading edge to trailing edge.

Card	Column	Code	Format	Explanation
V1	1-80		1X	Comment card which identifies the following vertical tail data.
V2	1-80		1X	Header Card
V3	1-10	FNOUT	F10.0	Number of grid points to be constructed on each vertical tail section. Typical value = 35.0
	11-20	AA1C	F10.0	Grid spacing specified at the L. E. of the V.tail to control grid distribution in chordwise (X) direction. This value must be normalized by the chord of the V.tail.

Card	Column	Code	Format	Explanation
	21-30	BB1C	F10.0	Grid spacing specified at the T. E. of the V. tail to control grid distribution in chordwise (X) direction. This value must be normalized by the chord of the V.tail.
	31-40	FKCUT	F10.0	Number of sections to be constructed on the V.tail in spanwise (Y) direction.
	41-50	AA1S	F10.0	Grid spacing specified at the root of the V.tail to control grid distribution in the spanwise (Y) direction. This value must be normalized by the span of the V.tail.
	51-60	BB1S	F10.0	Grid spacing specified at the tip of the V.tail to control grid distribution in the spanwise (Y) direction. This value must be normalized by the span of the V.tail.
V4	1-10	NSVTL	I10	Number of input section curves to describe the V.tail surface geometry.
				Note: The set of cards V5-V6 must be repeated NSVTL times.
V5	1-10	NVTL	I10	Number of points on the section curve.
				Note: Card V6 must be repeated NVTL times for each data set.
V6	1-15	XVTL	F15.7	X-coord. of a point on a V.tail section curve.
	16-30	ZVTL	F15.7	Z-coord. of the point.
	31-45	YVTL	F15.7	Y-coord. of the point.

High Horizontal Tail Definition

Input data for the high horizontal tail is formatted just like the strut input data.

Card	Column	Code	Format	Explanation
H1	1-80		1X	Comment card which identifies the following high horizontal tail data.
H2	1-80		1X	Header Card
H3	1-10	FNOUT	F10.0	Number of grid points to be constructed on a constant span section curve (including upper and lower surfaces) of the H.tail.
	11-20	AA1C	F10.0	Grid spacing specified at the L. E. of the H.tail to control grid distribution in the chordwise (X) direction. This value must be normalized by the chord of the H.tail.
	21-30	BB1C	F10.0	Grid spacing specified at the T. E. of the H.tail to control the grid distribution in the chordwise (X) direction. This value must be normalized by the chord of the H.tail.

	31-40	FKCUT	F10.0	Number of sections to be constructed on the H.tail in spanwise (Z) direction.
H3	41-50	AA1S	F10.0	Grid spacing specified at the root of the H.tail to control grid distribution in the spanwise (Z) direction. This value must be normalized by the span of the H.tail.
	51-60	BB1S	F10.0	Grid spacing specified at the tip of the H.tail to control the grid distribution in the spanwise (Z) direction. This value must be normalized by the span of the H.tail.
H4	1-10	NSHTL	I10	Number of H.tail input section curves to describe the H.tail upper and lower surface geometries.
				Note: The set of cards H5-H8 must be repeated NSHTL/2 times.
H5	1-10	NHTUP	I10	Number of points on the H.tail upper section curve.
				Note: Card H6 must be repeated NHTUP times for each data set.
H6	1-15	XHUP	F15.7	X-coord. of a point on the H.tail upper section curve.
	16-30	ZHUP	F15.7	Z-coord. of the point.
	31-45	YHUP	F15.7	Y-coord. of the point.
H7	1-10	NHTLO	I10	Number of points on the H.tail lower section curve.
				Note: Card H8 must be repeated NHTLO times for each data set.
H8	1-15	XHLO	F15.7	X-coord. of a point on the H.tail lower section curve.
	16-30	ZHLO	F15.7	Z-coord. of the point.
	31-45	YHLO	F15.7	Y-coord. of the point.

2.2.2 PREPARATION OF INPUT FILE grd2inp

File grd2inp contains parameters and switches which control the volume grid generation in program BEGRID2. Some parameters in this file were used to provide debugging options. These options are not used for production runs. Some parameters, for example the source control terms, were initially included in the input deck for parametric study to tailor-made the grid for aft-mounted configurations. These parameters may now be viewed as constants. The format of grd2inp is described below.

Card	Column	Code	Format	Explanation
1	1-80	TITLE	20A4	An 80-column title assigned to the run.
2	1-80		1X	Header Card
3	1-10	FTEST	F10.0	Program control parameter. Set it to 3.0

	11-20	FLM	F10.0	Program control parameter. Set it to 3.0
	21-30	FNSAV	F10.0	Refinement level of the output grid. Only relevant if mesh refinements is used. Set it to 1.0 Note: The current Euler flow solver requires only the fine grid. For mesh refinement in the flow solver, the solver extracts medium grid from the fine grid, and extracts coarse grid from medium grid.
	31-40	FMMRF	F10.0	Mesh refinement parameter for grid generation. Set it to -1.0
	41-50	FPRINT	F10.0	Print control parameter. Set it to 2.0
4	1-80		1X	Header Card
5	1-10	FIT1	F10.0	Number of iterations to be performed for 3D grid generation. Recommended value = 50.0
	11-20	FIT2	F10.0	Number of iterations to be performed for 2D grid generation at the root section. Recommended value = 100.0
	21-30	FIT3	F10.0	Number of iterations to be performed for 2D grid generation at the nacelle and the farfield sections. Recommended value = 100.0
	31-40	P1	F10.0	Overrelaxation factor used for volume grid generation. Recommended value = 1.70
	41-50	P2	F10.0	Overrelaxation factor used for surface grid generation at the wing root section. Recommended value = 1.70
	51-60	P3	F10.0	Overrelaxation factor used for surface grid generation at the nacelle and farfield sections. Recommended value = 1.70
	61-70	TOL	F10.0	Convergence tolerance. Grid solution is considered converged when its maximum residual is $\leq$ TOL. Recommended value = 0.001
6	1-80		1X	Header Card
7	1-10	FSYM	F10.0	Wing symmetry parameter which controls how airfoil section coordinates are read in. Set it to 2.0
	11-20	BODY	F10.0	Parameter that indicates the presence of a fuselage. $\geq$ 6.0 if the fuselage is present. $\leq$ 5.0 if there is no fuselage (not validated).

	21-30	DYFACN	F10.0	Distance in the J direction from the nacelle surface to the first grid line, normalized by the strut chord. Recommended value = 0.05
	31-40	FJBODY	F10.0	Assigned J index on the crown and keel lines of the fuselage. Typical value = 13.0 Note: FJBODY-1 = Number of cells on the fuselage surface in the J direction.
8	1-80		1X	Header Card
9	1-10	DYFAC	F10.0	Distance in the J direction from the wing surface to the first grid line, normalized by the wing chord. Recommended value = 0.02
	11-20 21-30	RFAC1 RFAC2	F10.0 F10.0	Ratio of the extent of the farfield in the J direction to the larger of the semispan or the fuselage body length. RFAC1 - at K=1 grid surface Typical value = 5.0 RFAC2 - at K=KMAX grid surface Typical value = 2.0
	31-40	ZFAC	F10.0	Ratio of the distance between the wing tip and the spanwise farfield to the larger of the semispan or the fuselage length. Typical value = 3.0
	41-50 51-60	FREAD FRD2	F10.0 F10.0	I/O unit numbers used to read in the geometry data files. Suggested values: FREAD = 12.0 (wing) FRD2 = 8.0 (fuselage) Each file must have a unique number. Do not use any of the following reserved numbers: 1, 7, 9, 10, 11, 13-19, 25, 31-33, 45, 46.
	61-70 71-80	YFAC YFAC2	F10.0 F10.0	Grid spacing parameters on the downstream farfield boundary. These values represent the distance over which the "body" I grid lines will be spread in the J direction. The numbers given are normalized by the wing chord at the given K station. Recommended values: YFAC = 1.0 (applied at K=1) YFAC2 = 2.0 (applied at K-KMAX)
10	1-80		1X	Header Card
11	1-10	FICKM	F10.0	Program control parameter. Set it to 1.0

	11-20 21-30 31-40	FISCL FJSCL FKSCL	F10.0 F10.0 F10.0	Source control parameters for volume grid generation in the I, J, and K directions respectively. Refer to Appendix A in Volume I, FISCL rescales the P term computed by Eq. (A4). FJSCL and FKSCL rescale the Q and R terms in Eqs. (A5) and (A6) respectively. Recommended value = 1.0 for all three.
	41-50	FJNAC	F10.0	Assigned J index on the crown and keel lines of the nacelle. Typical value = 7.0 Note: FJNAC-1 = Number of cells on the nacelle surface in the J-direction.
12	1-80		1X	Header Card
13	1-10 11-20	FISCL2 FJSCL2	F10.0 F10.0	Source control parameters for surface grid generation at the root section in the I and J directions, respectively. Refer to Appendix A in Volume I, FISCL2 and FJSCL2 rescale the P and Q terms in Eqs. (A4) and (A5) respectively. Recommend value =1.0 for both.
	21-30 31-40	FISCL3 FJSCL3	F10.0 F10.0	Source control parameters for surface grid generation at the nacelle and farfield sections in the I and J directions, respectively. Refer to Appendix A in Volume I, FISCL3 and FJSCL3 rescale the P and Q terms in Eqs. (A4) and (A5) respectively. Recommend value =0.9 for both.
	41-50	FDISC	F10.0	Parameter that indicates the presence of a propeller disk. =0.0 if there is no propeller disk. =1.0 if the propeller disk is present.
	51-60	DDISC	F10.0	Physical diameter of the propeller disk. Typical value = 10.0 Note: The specified value of DDISC is ignored when FDISC=0.0
14	1-80		1X	Header Card
15	1-10	CC1	F10.0	Source control parameter for elliptic grid generation. Recommended value = -1.0
	11-20	CC2	F10.0	Source control parameter for elliptic grid generation. Recommended value = 2.0
	21-30	CC3	F10.0	Source control parameter for elliptic grid generation. Recommended value = 1.0
	31-40	CC4	F10.0	Source control parameter for elliptic grid generation. Recommended value = 2.25
	41-50	CCZ	F10.0	Source control parameter for elliptic grid generation. Recommended value = 2.0

	51-60	STRMIN	F10.0	Minimum stretching factor. Recommended value = 1.2
	61-70	FIUBE	F10.0	Parameter that indicates the presence of an aft-mounted nacelle. FIUBE = FNACEL in page 6 and = FUBE in page 18. =1.0 if the nacelle is present. =0.0 if there is no nacelle.

Note for Cards 16-19: The K-station cut capability is used to visually examine the grid at desired K-stations. This data is written to file "kplane" in MPIX format. Each K-station cut contains eight networks.

16	1-80		1X	Header Card
17	1-10	NCUTS	F10.0	Total number of K-constant planes to be cut.
18	1-80		1X	Header Card
19	1-5	KSTATIONS	I5	1st K-station to be cut.
	6-10	KSTATIONS	I5	2nd K-station to be cut.
	11-15	KSTATIONS	I5	3rd K-station to be cut.
	16-20	KSTATIONS	I5	4th K-station to be cut. Note: When NCUTS=0.0, the specified values of KSTATIONS are ignored.
20	1-80		1X	Header Card
21	1-10 11-20 21-30	XDISC YDISC ZDISC	F10.0 F10.0 F10.0	Global X, Y, Z coordinates of the propeller disk center. Note: These values are only relevant when FDISC =1.0
	31-40	XTNAC	F10.0	Global X coordinate at which the plume surface grid will be cut off in those output files used for surface grid visualization. XTNAC has no effect on the grid generation process nor on the final grid produced XTNAC is different from the XTENAC in page 23.
22	1-80		1X	Header Card
23	1-10	FNAC	F10.0	Parameter that indicates the presence of a wing mounted nacelle. Set it to -1.0 for an aft-mounted nacelle airplane configuration.
	11-20	FIRD4	F10.0	I/O unit number used to read in the nacelle data. Recommended value = 4.0 Note: Comments made for inputs FREAD and FRD2 (Card 9) also apply here.
	21-30	FPER	F10.0	Not used. Set it to 0.0

31-40	FSMOD	F10.0	Grid smoothing parameter. Set it to -2.0
41-50	FKSTRUT	F10.0	Set it to 5.0
51-60	FKNACL	F10.0	Set it to 5.0

2.2.3 PREPARATION OF INPUT FILE components

This file is read by the grid smoothing program BEGRID3 and reformatting utility BEGRID4. It simply indicates which components are present in the grid files.

Card	Column	Code	Format	Explanation
1	1-80		1X	Header Card
2	1-10	FTAIL	F10.0	Parameter that determines the presence of a strut or conventional horizontal tail. FTAIL = FHTAIL in page 6. = 1.0 if this component is present. = 0.0 if there is no strut, nor conventional horizontal tail.
	11-20	FUBE	F10.0	Parameter that determines the presence of an aft-mounted nacelle. = 1.0 if the aft-nacelle is present. = 0.0 if there is no aft-nacelle.
	21-30	HVTAIL	F10.0	Parameter that determines the presence of a horizontal tail on the top of the vertical tail. HVTAIL = FHVTAIL in page 6. = 1.0 if the high horizontal tail is present. = 0.0 if there is no high horizontal tail.

2.2.4 PREPARATION OF FLOW ANALYSIS INPUT FILE flowInp

This file is required by the Euler flow analysis program and contains information regarding the flow conditions and other controlling parameters. Some parameters in this files were used to provide debugging options. These options are not used for production runs and these parameters are now fixed. Sample files are given in Appendix D.4.

Card	Column	Code	Format	Explanation
1	1-80	TITLE	10A8	Title to be used as a heading on the several output files produced by the code. This line should contain enough information to uniquely identify the run. For example, configuration identification, flight conditions, etc.
2	1-80		1X	Header Card

3	1-10 11-20 21-30	FNX FNY FNZ	F10.0 F10.0 F10.0	Number of grid cells in the I, J, K directions of the computational domain for the initial mesh. Compute these values by dividing the number of cells on the finest mesh by the quantity 2** (FMESH-FA). Program execution will be stopped when FNX is zero or negative. Explanations for FA and FMESH are given below.
	31-40	FA	F10.0	The grid level at which to start the solution. = 1.0 if starting from scratch. = FMESH for a continuation run.
	41-50	FMESH	F10.0	Grid sequencing levels in the Euler calculation. The flow solution in the coarser grid is interpolated onto the next finer grid to provide an starting gusess. Current choices are: = 1.0 for no grid sequencing. = 2.0 for two levels of grid sequencing. = 3.0 for three levels of grid sequencing. Please see the Euler code flow chart on page 47 and the sample files in Appendix D.4 for further details.
	51-60 61-70 71-80	FIDIM FJDIM FKDIM	F10.0 F10.0 F10.0	The number of grid points per computational block in the I, J, and K directions respectively. These numbers determine both the size of a computational block and the number of blocks used in each direction. Input the following values: FIDIM = FNX + 1.0 (no division in I dir.) FJDIM = (FNY/number of blocks in J dir.) + 1.0 FKDIM = (FNZ/number of blocks in K dir.) + 1.0 Note: The number of blocks required in each direction depends upon the amount of machine memory available and on the model's geometric complexity. The sample input file in Appendix D.4.1 divides the flowfield into three blocks in J and two blocks in K. The blocking in J is for placing the high horizontal tail on the block boundary. The initial check out run was conducted on a CRAY X-MP using 2.5 MW of memory for which the additional blocking in K was required.
4	1-80		1X	Header Card Note: Card 5 must be repeated FMESH times. Each data line defines information for one grid level. The information is provided for coarse to fine. See example on page 61, Appendix D.4.2.
5	1-10	FCYC	F10.0	Number of multigrid cycles in one grid level, if FPRNT ≥ FCYC only final printout will be printed.
	11-20	FPRNT	F10.0	Number of multigrid cycles between each print out.
	21-30	FTIM	F10.0	Number of multi-grid cycles per time step calculation.

	31-40	GPRNT	F10.0	Option to obtain additional print out. = -1.0 suppress mesh and flow field printout. = 0.0 normal print out. = 1.0 print grid coordinates and cell volumes. = 2.0 print grid coordinates, cell volumes, and flow field formation.
	41-50	HPRNT	F10.0	Print grid and flow field information for every HPRNT points in the I (wrap around) direction and K (span) direction.
	51-60	GMESH	F10.0	The number of multigrid stages to use on this grid level.
	61-70	CFLFI	F10.0	Unused if non-positive. CFL number = CFLFI if it is positive. In this case CFLFI over-ride the CFLF in Card 9 in this file. Recommended value = 0.0
	71-80	CFLCI	F10.0	Unused if non-positive. CFL number for coarse grid= CFLCI if it is positive. In this case CFLFI over-ride the CFLC in Card 15 in this file. Recommended value = 0.0
6	1-80		1X	Header Card
7	1-10	FSTART	F10.0	Euler solution starting option. = 0.0 start from scratch. = 1.0 continuation run.
	11-20	GINFIL	F10.0	Restart file unit number. Only relevant for continuation runs. Set = 10.0
	21-30	RTRMSO	F10.0	Set = 0.0
	31-40	FNCYBL	F10.0	Set = 10000.0
	41-50	WNECK	F10.0	Switch to activate wake contraction for the wing and horizontal tail when the wing and tail geometries are corrected by boundary layer displacement thickness. This option can affect the results only for a wing with a finite thickness trailing edge. = 1.0 Model the wake contraction effect ≤ 0.0 Assume no wake contraction Recommended value = 1.0
	51-60	SMESH	F10.0	Set = 3.0
	61-70	FTYPE	F10.0	Set = 1.0
	71-80	FTTAIL	F10.0	T-tail flag (t-tail = high horizontal tail). =0.0 T-tail off. =1.0 T-tail on.
8	1-80		1X	Header Card

9	1-10	CFLF	F10.0	CFL number. Negative CFL implies the use of local time stepping. Positive CFL implies time-accurate time stepping. Recommended value = -6.0
	11-20	BC	F10.0	Wing surface boundary condition flag. = -1.0 use the normal momentum relation to compute wing surface pressure. = 0.0 use cell center value to approximate the wing surface pressure. Recommended value = -1.0
	21-30	QFIL	F10.0	Filter evaluation flag for Runge-Kutta steps. = 1.0 evaluate twice for each time step. = 0.0 evaluate once for each time step. Recommended value = 1.0
	31-40	VIS2	F10.0	Coefficient for second order dissipation. Typical value = 2.0.
	41-50	VIS4	F10.0	Coefficient for fourth order dissipation. Typical value = 2.0.
	51-60	HFACTOR	F10.0	Coefficient for enthalpy damping = 0.2 if total energy level is uniform. = 0.0 for a flowfield with different total energy levels. Typical value = 0.2.
	61-70	GTYP	F10.0	Switch indicating the format of the input grid data. Set = 0.0 to be compatible with the previously described grid generation programs.
	71-80	ALLM	F10.0	Switch specifying whether surface results are stored for all meshes. A list of files for storing such results can be found in subsection 3.2. =0.0 store results for finest mesh only =1.0 store results for all meshes Recommended value =0.0
10	1-80		1X	Header Card
11	1-10 11-20 21-30 31-40 41-50 51-60	C1 C2 C3 C4 C5 C6	F10.0 F10.0 F10.0 F10.0 F10.0 F10.0	C1 to C6 are coefficients for multistage Runge-Kutta integration steps. The following values are for a five stage scheme. C1 = 0.25 C4 = 0.5 C2 = 0.166667 C5 = 1.0 C3 = 0.375 C6 = 0.0
12	1-80		1X	Header Card
13	1-10 11-20 21-30	SMOOPI SMOOPJ SMOOPK	F10.0 F10.0 F10.0	Implicit smoothing parameters in the I, J, and K directions respectively. Recommended value for each =2.5
14	1-80		1X	Header Card

15	1-10	FITD0	F10.0	Number of Euler integrations in each grid level in a V-cycle multigrid from the finest to the coarsest grids. Set = 1.0
	11-20	FITUP	F10.0	Number of Euler integrations in each grid level in a V-cycle multigrid from the coarsest to the finest grids. Set = 0.0. This means interpolation only.
	21-30	CFLC	F10.0	CFL number for the coarse grid. Recommended value = -6.0
	31-40	HMC	F10.0	Enthalpy damping coefficient for coarse grid. Set = 0.0
	41-50	FBC	F10.0	Set = 1.0
	51-60	FCOLL	F10.0	Set = 1.0
	61-70	FADD	F10.0	Set = 1.0
	71-80	VI	F10.0	Dissipation coefficient for coarse grid. Recommended value = 2.0
16	1-80		1X	Header Card
17	1-10	FMACH	F10.0	Freestream Mach number.
	11-20	ALPHA	F10.0	Angle of attack in degrees.
	21-30	ALYAW	F10.0	Angle of yaw in degrees.
	31-40	FIRUN	F10.0	Option to initialize the Euler calculation with a computed solution obtained at different freestream conditions. ≤ 0.0 start from scratch or restart from a run with the same freestream conditions. = 1.0 start from a run with different freestream conditions.
	41-50	RMOLD	F10.0	Freestream Mach number of previous run.
	51-60	ALOLD	F10.0	Angle of attack in degrees of previous run.
	61-70	ALYWOLD	F10.0	Angle of yaw in degrees of previous run.
	71-80	CD0	F10.0	Estimate of the viscous drag coefficient. Set = 0.0 if an estimate is not available.
18	1-80		1X	Header Card
19	1-10	AREF	F10.0	Wing reference area. See note below.
	11-20	XREF	F10.0	Longitudinal location of the moment reference point.
	21-30	YREF	F10.0	Span location of the moment reference point.
	31-40	ZREF	F10.0	Vertical location of the moment reference point.

	41-50	CREF	F10.0	Pitching moment reference length.
	51-60	SREF	F10.0	Yawing and rolling moment reference length. Note: The units of AREF, CREF, and SREF should be consistent with the units of the wing geometry data. For example, if the wing data is given in inches then CREF and SREF should be in inches, while AREF should be square inches.
20	1-80		1X	Header card.
21	1-10	FSCZ	F10.0	Flag for dissipation term scaling in spanwise direction. = 1.0 for scaling. = 0.0 for no scaling. Recommended value = 0.0
	11-20	CC1	F10.0	Scaling coefficient at wing root. Set = 1.0
	21-30	CC2	F10.0	Scaling coefficient at wing tip. Set = 1.0
	31-40	FIYAW	F10.0	Airplane flowfield left and right symmetry flag. ≤ 0.0 Symmetric. = 1.0 Nonsymmetric. Note: FISTFL, FINCLF, and FIPPLF are used only if FIYAW =1.0
	41-50	FISTLF	F10.0	Flag for left strut. = 1.0 Strut on. ≤ 0.0 Strut off.
	51-60	FINCLF	F10.0	Flag for left nacelle. = 1.0 Nacelle on. ≤ 0.0 Nacelle off.
	61-70	FIPPLF	F10.0	Flag for left propeller disk. = 1.0 Propeller disk on. ≤ 0.0 Propeller disk off.
	71-80	FMVTL	F10.0	Vertical tail option flag. = 1.0 Vertical tail on. ≤ 0.0 Vertical tail off.
22	1-80		1X	Header card.
23	1-10	FTAIL	F10.0	Flag for horizontal tail or aft-mounted propfan strut. = 1.0 on. ≤ 0.0 off.

	11-20	FIBODY	F10.0	Fuselage boundary condition flag. = -1.0 for normal momentum. = 11.0 for cell centered. Recommended.value = 11.0
	21-30	FITEBC	F10.0	Set = 1.0
	31-40	FMNAC	F10.0	Flag for right side aft-mounted nacelle. = 1.0 nacelle on. = -2.0 nacelle off.
	41-50	GRDN	F10.0	Set = 0.0
	51-60	FMDSK	F10.0	Flag for right side propeller disk. = 0.0 Propeller disk off. = 1.0 Propeller disk on.
	61-70	XTENAC	F10.0	X-coordinate of the nacelle fan cowl's trailing edge. XTENAC is different from XTNAC in page 17.
	71-80	WINGLET	F10.0	Set = 0.0
24	1-80		1X	Header Card
25	1-10	FMTYPE	F10.0	Method of propeller disk simulation, ignored if FMDSK = 0.0 Set = 2.0 when FMDSK = 1.0 More flexibility in type of disk simulation is provided in the inputs to the embedded code.
	11-20	FIRDSK	F10.0	Number of radial stations at which propeller loading is described. Note: There must be FIRDSK data lines under Card 29.
26	1-80		1X	Header Card
27	1-10 11-20 21-30	XDSK0 YDSK0 ZDSK0	F10.0 F10.0 F10.0	The x, y, z coordinates of the propeller disk's center. These coordinates should equal the x, y, z input in Card 21 in grd2inp file.
	31-40	RDSK	F10.0	The radius of the disk. RDSK ≤ DDISC/2 in Card 13 in grd2inp file.
28	1-80		1X	Header card.
29	1-10	RDS	F10.0	Radial distance, measured from the propeller disk's center, at which loading is defined.
	11-20	THRUST	F10.0	Thrust coefficient of the propeller disk.
	21-30	FNORMAL	F10.0	Normal force coefficient of the propeller disk.
	31-40	FSPAN	F10.0	Side force coefficient of the propeller disk.

	41-50	WORK	F10.0	Work done by the propeller disk.
30	1-80		1X	Header card.
31	1-10	FNCUT	F10.0	Number of constant x-planes where flow field will be saved. FNCUT should be $\leq$ 8.0 Set = 0.0 if you do not want to save such flow field information. Note: The following three inputs can be used to cut the above mentioned x-planes at constant Y values, thus producing flow data along lines.
	11-20 21-30	YWTR0 DYWTR	F10.0 F10.0	Initial Y value and delta Y value used to make the above mentioned cuts.
	31-40	FNWTR	F10.0	The number of such y-cuts to make. To suppress this feature, Set =0.0
32	1-80		1X	Header card.
33	1-10 11-20	XCUT(1) XCUT(2) . . . . XCUT (FNCUT)	F10.0 F10.0	The x-coordinates of the constant x-planes at which to save the flow field.
34	1-80	TITLE	10A8	Type in "END OF CALCULATION".
35	1-80		1X	Header Card
36	1-10	FNX	F10.0	Set = 0.0 to stop the program execution.

2.3 GRID EMBEDDING

2.3.1 OPERATION OF THE PROGRAM FOR THE EMBEDDED SOLUTION

Running of the embedded solution program consists of four steps. The first step is to make available the field grid file "eulergrid" and flow field solution file "ffslnglb" from the global flowfield solutions. The second step is to run the embedded grid generation code EMBGG to generate the computational grid "fgemb" for the local embedded region. Three input files need to be prepared for this. File "nac" provides the nacelle geometry definition with cuts at constant x station. File "str" defines the strut geometry with sections cuts. Another small file "embginp" controls the dimension of the grid and other numerical parameters used in the embedded grid generation. Instructions to prepare "embginp", "nac" and "str" are given in the subsection 2.3.2.1. In the second step, a surface grid file "sgemb" is also generated for surface grid visualization.

The third step is to run the interpolation program INTPP for the interpolation of the global flowfield solution onto the locally embedded grid. Three already created files, "fgemb", "eulergrid", "ffslnglb", are required input files for this program. In addition, a small input file "intpinp" is required. This file can be prepared following the directions of subsection 2.3.2.2. This program output file, "ffslnint", interpolates the global flowfield solution onto the local embedded grid.

The fourth step is the running of the embedded Euler solver EMBFS. Two files generated previously, "fgemb" and "ffslnint", are the required input files. In addition, a small input file, "embfinp", is required to define the flow condition and the numerical parameters for running the embedded Euler flow solver. For embedded Euler calculations, the input freestream Mach number FMACH and angle of attack ALPHA (both input from Card 9 in file "embfinp") must be the same as that in the global run. Output of this program is discussed in Section 3. Execution procedure under the Network Queueing System for the grid embedded solution is given in Appendix C.3. Figure 2 summarizes the execution sequence and input -output for the embedded solution.

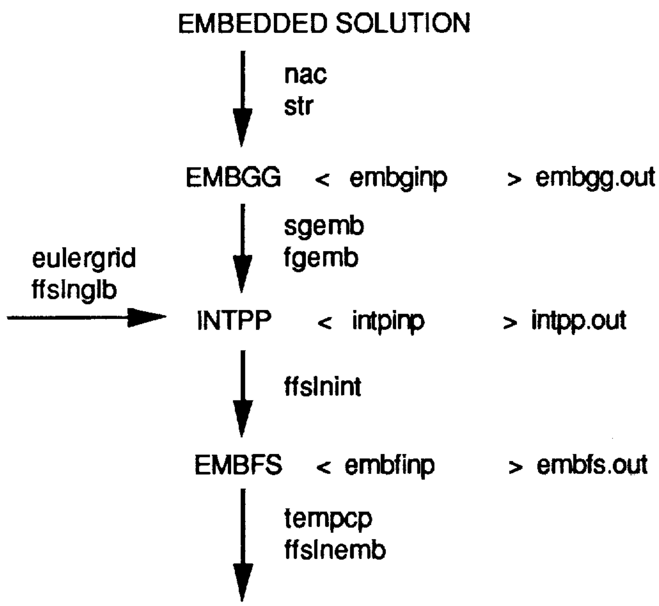


Figure 2. Grid embedding. Executable programs are shown in upper case. Files are shown in lower case. The "<" and ">" symbols denote input and output respectively.

2.3.2. INPUT DESCRIPTION

2.3.2.1. PREPARATION OF INPUT FILE FOR EMBEDDED GRID GENERATION

The input data for embedded grid generation program are described in the following section:

Card	Column	Code	Format	Explanation
1	1-80			Header Card
2	1-10	FIMX	F10.0	Number of grid points in i-direction. Typical value = 101.0
	11-20	FJMX	F10.0	Number of grid points in j-direction. Typical value = 21.0
	21-30	FKMX	F10.0	Number of grid points in k-direction. Typical value = 25.0
	31-40	FNTYP	F10.0	Inactive. Default = 0.0

	41-50	FSTYP	F10.0	Inactive. Default = 0.0
3	1-80		1X	Header Card
4	1-10	FNAC	F10.0	Nacelle input control. = 1.0 for one side only. = 2.0 input both sides (nonsymmetry). The plane of symmtry is aligned with the strut plane.
	11-20	FSTR	F10.0	Strut input control. = 1.0 for one side only. = 2.0 input both sides (nonsymmetry).
	21-30	FNACSI	F10.0	Nacelle strut intersection control. = 0.0. provide intersection line, points on strut and nacelle match. = 1.0 provide intersection line, points on strut and nacelle may not match.
	31-40	FYZ	F10.0	Parameter controls approximate orientation of strut. = 0.0 for vertical orientation. = 1.0 for horizontal orientation.
	41-50	FKFULL	F10.0	Grid option. = 0.0 full 3D grid. = 1.0 with plane of symmetry.
5	1-80		1X	Header Card
6	1-10	FMDSK	F10.0	Propeller disk control parameter. = 0.0 disk off. = 1.0 disk on.
	11-20	XDSK	F10.0	Propeller disk center point. x-coordinate.
	21-30	YDSK	F10.0	y-coordinate.
	31-40	ZDSK	F10.0	z-coordinate.
	41-50	RDSK	F10.0	Propeller radius.
7	1-80		1X	Header Card
8	1-10	FICU	F10.0	Number of grid blocks in i-direction + 1 Typical value = 5.0
9	1-80			Header Card
10	1-10	FIOCU(1) : :	F10.0	Minimum i-index of 1st block. Typical value = 1.0
	11-20	FIOCU(2)	F10.0	2nd block. Typical value = 21.0

		FIOCU(ICU)	F10.0	The i-index corresponding to nacelle trailing edge. Typical value = 85.0
11	1-80		1X	Header Card
12	1-10	FJCU	F10.0	Number of grid blocks in j-direction + 1 Typical value = 3.0
13	1-80		1X	Header Card
14	1-10	FJOCU(1)	F10.0	Minimum j-index of the first block. Typical value = 1.0
	11-20	FJOCU(2) : :	F10.0	2nd block Typical value = 13.0
		FJOCU(JCU)	F10.0	Maximum j-index of the last block. Typical value = 21.0
15-18				Same as cards 11-14 for k-direction.
19	1-80		1X	Header card
20	1-10	DYFAC	F10.0	First grid size in circumferential direction in terms of fraction of maximum circumference of the nacelle. Typical value = 0.015
	11-20	YFAC	F10.0	Farfield location in terms of strut chord. Typical value = 1.5
	21-30	XFAC	F10.0	Downstream farfield location in terms of nacelle length. Typical value = 2.0
21	1-80		1X	Header card
22	1-10	FITK1	F10.0	Number of iterations for k=1 plane. Recomended value = 50.0
	11-20	FITK2	F10.0	Number of iterations for k=kmx plane. Recomended value = 50.0
	21-30	FIT3D	F10.0	Number of iterations for 3-D grid genration. Recomended value = 50.0
	31-40	TOL	F10.0	Convergence tolerance. Recomended value = 0.001
23	1-80		1X	Header Card
24	1-10	P1	F10.0	Relaxation parameter for k = 1 Recomended value = 1.5
	11-20	P2	F10.0	Relaxation parameter for k = kmx Recomended value = 1.5
	21-30	P3	F10.0	Relaxation parameter for 3-D iterations. Recomended value = 1.5

	31-40	FICTL	F10.0	Grid control parameter in i-direction. Recomended value = 1.0
	41-50	FJCTL	F10.0	j-direction. Recomended value = 0.5
	51-60	FKCTL	F10.0	k-direction. Recomended value = 1.0
25	1-80		1X	Header Card
26	1-10	FKCUT	F10.0	Number of k-plane grids to be examined Typical value = 3.0
27	1-80		1X	Header card
28	1-10	KCUT1	F10.0	1st k-plane. Typical value = 13.0
	11-20	KCUT2 : :	F10.0	2nd k-plane. TYpical value = 13.0
		KCUTL	F10.0	last k-plane to be examined. Typicalvalue = 25.0
29-32				Same as Cards 25-28, but j-plane.
33-36				Same as cards 25-28, but for i-plane.

In addition to this input file, the strut geometry definition file "str", and the nacelle geometry definition file "nac" are required input. The strut geometry is prepared in a section by section manner, from fuselage strut intersection to strut nacelle intersection, and from upper surface leading edge to upper surface trailing edge, followed by lower surface leading edge to lower surface trailing edge. The nacelle geometry is split into two parts along the nacelle strut intersection plane. The lower surface coordinates at constant x cut from nose to tail are input first, followed by the upper surface coordinates. A sample input is attached (in Appendix D.5).

The sample inputs are not identical to the nacelle and strut definitions for the global grid because that the global solution method does not model the nacelle inlet and treats the nacelle as a domed nacelle. The embedded solution models the nacelle with an inlet.

Sample Input File str

```
NASA PROPFAN STRUT GEOMETRY INPUT SAMPLE
         3 (Number of cuts, each cut has two difinitions, 3 cuts=6 definitions)
        52 (Number of points on upper surface definition)
     96.2194672      5.5776601      2.8724599
     96.2644424      5.5443201      2.9300599
     96.4525604      5.4749999      3.0412900
     96.6665268      5.4274998      3.1131101
     96.8879013      5.3896499      3.1659601
     97.1128235      5.3579702      3.2066700
     97.3398590      5.3310599      3.2380600
     97.5682831      5.3081198      3.2617600
     97.7976227      5.2886300      3.2787399
     98.0275269      5.2721200      3.2899599
     98.2578430      5.2584801      3.2956700
     98.4883728      5.2476602      3.2959499
```

Sample Input File nac

```
NASA PROPFAN NACELLE GEOMETRY INPUT SAMPLE
        74 (Total number of definitions, 74 definitions=37 cuts)
        13 (Number of points at each definitions)
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
```

2.3.2.2. PREPARATION OF INPUT FILE FOR SOLUTION INTERPOLATION

This file is required by the interpolation program. An sample file is given in Appendix D.6.

Card	Column	Code	Format	Explanation
1	1-80		10A8	Heeader Card
2	1-10	FNX	F10.0	Number of grid cells in the wrap-around direction in the fine mesh divided by IREDU where IREDU=2**(FMESH-FA). Explanations for FA and FMESH are given in column 31-40, and 41-50 of this card respectively.
	11-20	FNY	F10.0	Number of grid cells in the normal direction in the fine mesh divided by IREDU.
	21-30	FNZ	F10.0	Number of grid cells in the span direction in the fine mesh divided by IREDU.
	31-40	FA	F10.0	Unused here Default = 0.0
	41-50	FMESH	F10.0	Unused here Default = 0.0
	51-60	FIDIM	F10.0	FNX + 1.0
	61-70	FJDIM	F10.0	FNY/JBLK + 1.0, where JBLK in the number of blocks in the normal direction. I.e., JBLK is determined from FNY and FJDIM by JBLK = FNY/(FJDIM-1).
	71-80	FKDIM	F10.0	FNZ/KBLK + 1.0, where KBLK in the number of blocks in the span direction. I. e., KBLK = FNZ/(FKDIM-1).

2.3.2.3 Preparation of Input File for Embedded Euler Solver

This file is required by the Embedded Euler flow and analysis program and contain information regarding the flow condition and other controlling parameters. Note that the global solution uses a solid plume while the embedded solution allows boundary condition specification on the nacelle exit plane using the parameters in Card 11 in this file. In addition, embedded solver also allows boundary condition specification on the fan face inlet (Card 11) while the global solution assumes a domed nacelle. Refer to Appendix C in Volume I for further details. Some parameters in this file were used to provide debugging options. These options are not used for production runs and these parameters are now fixed. Sample input files are given in Appendix D.7.

Card	Column	Code	Format	Explanation
1	1-80		10A8	Title to describe the run output data. The title should include sufficient information such that the user can identify his run at a later time, e.g., the configuration identification, the flight conditions, Mach, alpha, etc.
2	1-80			Header Card

3	1-10	FNX	F10.0	Number of grid cells in the wrap-around direction in the fine mesh divided by IREDU where IREDU=2** (FMESH-1). Explanations for FMESH are given in column 31-40 of this card. Typical value = 100.0
	11-20	FNY	F10.0	Number of grid cells in the normal direction in the fine mesh divided by IREDU. Typical value = 20.0
	21-30	FNZ	F10.0	Number of grid cells in the span direction in the fine mesh divided by IREDU. Typical value = 24.0
	31-40	FMESH	F10.0	Grid sequencing levels up to two levels. =1.0 for no grid sequencing (see Appendix D.7.1). =2.0 for two levels of grid sequencing (see Appendix D.7.2). FMESH is equal to the number of Card 5's in the input Always set FMESH = 1.0 for the calculationof local embedded solutions. Algorithm logic is similar to that shown in the flow chart for the global solver (pg. 47) except that here we have a single block.
	41-50	FCONT	F10.0	Option to start the Euler solution. = 0.0 start from scratch. = 1.0 Embedded flow calculation with farfield boundary data interpolated from the global solution ≥ 2.0 continuation run.
	51-60	FAGPS	F10.0	Option to save surface Cp plot file. = 1.0 save the plot file. = 0.0 do not save the plot file.
4	1-80		1X	Header Card
5				The number of Card 5's must be equal to FMESH. Each one Card 5 define information for one grid level. For the calculation of local embedded solutions, FMESH = 1.0 only one Card 5 should be used.
	1-10	FEND	F10.0	Number of time steps in one grid level. Typical value = 500.0.
	11-20	FPRNT	F10.0	Number of time steps per one print out.
	21-30	FOUT	F10.0	Number of time steps per each print out of convergence history. Recomended value = 2.0
	31-40	FTIM	F10.0	Number of time steps per time step calculation. Recomended value = 5.0

	31-40	GPRNT	F10.0	Option to obtain additional print out. = 0.0 normal print out. = 1.0 print grid coordinates and cell volume. = 2.0 print grid coordinates and cell volume and flow field information.
	51-60	HPRNT	F10.0	Print grid and flow field information for every HPRNT points in the I (wrap around) direction and K (circumferential) direction.
	61-70	HMMH	F10.0	Coefficient for enthalpy damping. = 0.2 if total energy level is uniform. = 0.0 for flow field with different total energy level.
	71-80	PSMOOV	F10.0	Implicit smoothing parameter. Recomended value = 0.0
6	1=80		1X	Header Card
7	1-10	CFL	F10.0	CFL number. Negative CFL implies the use of local time stepping. Positive implies time accurate time stepping. Recomended value = -2.5
	11-20	BC	F10.0	Fan cowl surface boundary condition flag. = -1.0 for normal momentum relation to compute fan cowl surface pressure. = 0.0 use cell center value to approximate fan cowl surface pressure.
	21-30	QFIL	F10.0	Filter evaluation flag. = 1.0 evaluate four time for every time step. = 0.0 evaluate once for every time step.
	31-40	VIS2	F10.0	Coefficient for second order dissipation. Recomended value = 1.0
	41-50	VIS4	F10.0	Coefficient for fourth order dissipation. Recomended value = 0.5
8	1-80		1X	Header Card
9	1-10	FMACH	F10.0	Freestream Mach number. Same as the FMACH in the global run for embedded Euler calculation.
	11-20	ALPHA	F10.0	Angle of attack in degrees. Same as the ALPHA in the global run for embedded Euler calculation.
	21-30	CDO	F10.0	An estimation of viscous drag coefficient.
	31-40	YAW	F10.0	Angle of yaw in degrees.
	31-40	FIBCW	F10.0	= 1.0

	41-50	FIGUS	F10.0	= 0.0
	51-60	FJSCAL	F10.0	Option flag for scaling the dissipation terms. = 0.0 use pressure sensor to scale the 2nd order dissipation term. = 1.0 use pressure sensor to scale the 2nd order dissipation term. Linearly scales the dissipation terms to zero at the surface of center body (or domed nacelle) and the surface of the fan cowl (or farfield). = 2.0 use density sensor to scale the 2nd order dissipation term. Linearly scales the dissipation term to zero at the surface of center body (or domed nacelle) and the surface of the fan cowl (or farfield). = 3.0 use total pressure sensor to scale the 2nd order dissipation term. Linearly scales the dissipation terms to zero at the surface of center body (or domed nacelle) and the surface of the fan cowl (or farfield).
10	1-80		1X	Header Card
11	1-10	FMIN	F10.0	Option flag for fan face inlet boundary condition. = 1.0 normal velocity boundary condition at fan face, specify QIN. = 2.0 pressure boundary condition at the fan face, specify PIN. = 3.0 mass flux boundary condition at fan face, specify RQIN.
	11-20	QIN	F10.0	Flow speed (normalized by freestream condition) at the nacelle fan face.
	21-30	PIN	F10.0	Pressure (normalized by freestream condition) at the nacelle fan face.
	31-40	RQIN	F10.0	Mass flux density (density times flow speed, normalized by freestream condition) at the nacelle fan face.
	41-50	FMOUT	F10.0	Option flag for fan exhaust boundary condition. = 1.0 freestream exhaust = 2.0 freestream total temperature with a specified total pressure PSTGO = 3.0 specify both total pressure PSTGO and total temperature TSTGO.
	51-60	PSTGO	F10.0	Total pressure (normalized by freestream static pressure) at the nacelle exit plane. Used only if FMOUT = 2.0 or 3.025
	61-70	TSTGO	F10.0	Total pressure (normalized by freestream static temperature) at the nacelle exit plane. Used only if FMOUNT = 3.0
12	1-80		1X	Header Card

13	1-10	AINFTY	F10.0	Inlet capture area at infinity in units consistent with the geometry definition (used only if FMIN = 1.0).
	11-20	REFA	F10.0	Nacelle reference area. The units of REFA should be consistent with the nacelle geometry data. For example, if the geometry is in inches than REFA should be in square inches.
	21-30	FKSYM	F10.0	Flag to indicate whether flow is axi-symmetric or 3D. = 0.0 3D flow. = 1.0 axi-symmetric flow.
	31-40	FDAFT	F10.0	Option to over-write the QIN in Card 11 (when FMIN = 1.0). = 0.0 Compute the QIN based on AINFTY to over-write the QIN in Card 11. = 1.0 use the QIN in Card 11.
	41-50	FIFLO	F10.0	Flag for nacelle type. = 0.0 for powered nacelle. = 1.0 for flow through nacelle. = 5.0 for domed nacelle.
	51-60	FKSMLR	F10.0	Flag for Euler calculation assuming one plane of symmetry for a nacelle/strut that has an one plane of symmetry geometry. = 0.0 Euler calculation without one plane of symmetry assumption. = 1.0 Euler calculation with one plane of symmetry assumption.
	61-70	FNBC	F10.0	Number of iterations for surface pressure calculation. Recomended value = 1.0
	71-80	BCST	F10.0	Strut surface boundary condition flag. = -1.0 for normal momentum relation to compute strut surface pressure. = 0.0 use cell center value to approximate strut surface pressure.
14	1-80		1X	Header Card
15	1-10	FIXYUV	F10.0	Control velocity plot on the symmetry plane = 0.0 plot file will not be written. = 1.0 plot file will be written on FT19.
	11-20	FINET	F10.0	Number of grid cells divided by 6 starting from I index for the fan face inlet (starting from I = 1 for domed nacelle). Typical value = 7.0
16	1-80		1X	Header Card

17	1-10	FIXYM	F10.0	Control Mach number, velocity and pressure plot in the exhaust region, aft of trailing edge. = 0.0 plot file will not be written, use this option if there is no exit plane. = 1.0 plot file will be written on FT21.
	11-20	FIDEL	F10.0	Number of grid cells starting from exit plane and downstream to define the domain of the plot. Typical value = 25.0
18	1-80		1X	Header Card
19	1-10	FIYZVW	F10.0	Control velocity plot at specified x/c (x-coordinate normalized by the length of the nacelle) cuts. = 0.0 plot file will not be written. = 1.0 plot file will be written on FT20.
	11-20	FINET2	F10.0	Number of velocity plots at various x/c cuts.
	21-30	XOCS	F10.0	The starting x/c value, i. e., x/c for first cut; must be greater than zero.
	31-40	DXOC	F10.0	x/c increment for succeeding cut.
20	1-80		1X	Header Card
21	1-10	FIYZFF	F10.0	Control velocity and pressure plot at the fan face. = 0.0 plot file will not be written. = 1.0 plot file will be written on FT22.
22	1-80		1X	Header Card
23	1-10	FIBLC	F10.0	Option to read in surface transpiration on the fan cowl (or domed nacelle) surface = 0.0 do not read in surface transpiration. = 1.0 read in surface transpiration.
	11-20	FINBL	F10.0	= 0.0
	1-10	FNBCFX	F10.0	= 0.0
	11-20	C1	F10.0	= 0.0
24	1-80		1X	Header Card
25	1-10	FMDSK	F10.0	Method of propeller disk simulation, ignored if FMDSK=0. = 1.0 specify RPM, blade number, pitching angle in Card 25. This option is untested. = 2.0 input thrust, normal and side forces in card 31. = 3.0 input total pressure, total temperature, and swirl angle in card 31.
	11-20	RPM	F10.0	RPM of the propeller, used with FMDSK = 1.0.

	21-30	FNB	F10.0	Blade number, used with FMDSK = 1.0
	31-40	CINF	F10.0	Dimensional sound speed at infinity in units consistent with the geometry definition, used with FMDSK = 1.0
	41-50	FMRF1	F10.0	Typical value = 0.7
26	1-80		1X	Header Card
27	1-10	XDSK0	F10.0	The x-coordinate at the center of the disk.
	11-20	YDSK0	F10.0	The y-coordinate at the center of the disk.
	21-30	ZDSK0	F10.0	The z-coordinate at the center of the disk.
	31-40	RDSK	F10.0	The radius of the disk.
28	1-80		1X	Header Card.
29	1-10	FIRDSK	F10.0	Number of input cards in Card 31.
	11-20	PSTAT	F10.0	Dimensional static pressure in PSI.
	21-30	TTCHK	F10.0	= 0.0
30	1-80		1X	Header Card.
31	1-10	RDIN	F10.0	Radial distance from the center of the propeller disk at which loading is defined.
	11-20	PTIN	F10.0	Thrust coefficient of the propeller disk if FMDSK = 2.0 or total pressure (normalized by freestream static pressure) immediately downstream of the propeller disk if FMDSK = 3.0
	21-30	TTIN	F10.0	Normal force coefficient of the propeller disk if FMDSK = 2.0 or total temperature (normalized by freestream static temperature) immediately downstream of the propeller disk if FMDSK = 3.0
	31-40	SWIN	F10.0	Side force coefficient of the propeller disk if FMDSK = 2.0 or swirl angle in degree immediately downstream of the propeller disk if FMDSK = 3.0, looking aft, clockwise swirl is positive.

2.4 INCORE EULER ANALYSIS PROGRAM

An earlier version of PFE889, which did not subdivide the computational region into blocks, can also be used under the UNICOS operating system on a Cray-2 computer. Like PFE889, this code was developed under the COS operating system and then converted to run under UNIX. Porting the code involved the same considerations as for PFE889. These are mentioned in appendix A.

A sample script to run this incore Euler program is given in appendix section C.5. Reference 2 provides a detailed description and users manual for the program.

2.5 STREAMLINE TRACING PROGRAM

2.5.1 DESCRIPTION

SL3D uses an Euler predictor/corrector scheme to integrate the streamline equations. The streamline equations are given by

$$\bar{V} \times d\bar{S} = 0$$

or

$$V_y\,dz - V_z\,dy = 0$$
$$V_z\,dx - V_x\,dz = 0$$
$$V_x\,dy - V_y\,dx = 0$$

A large number (250) of streamlines can be computed with points of origin anywhere in the flowfield and can be integrated upstream or downstream.

The flowfield is divided into one or more "data groups" which can contain one or more "data sets". The "data group" level is intended to provide a means for integrating streamlines in flowfields with a very large number of locations which can not fit in central memory. SL3D works with only one "data group" at a time. Each "data group" must fit in central memory. The "data set" level is intended to provide a means for breaking each "data group" into regular rectangular blocks in computational space. Grid structures such as a C-grid or O-grid must be split in half such that no two boundaries within one "data set" connect to each other. The boundaries between different "data sets" and "data groups" have no restrictions. Tetrahedral and unstructured grids can not be worked by SL3D. Since the streamline program is a stand-alone code, some inputs that were required for the flow code (e.g. Mach, Alpha) must necessarily be repeated in the following input decks.

2.5.2 PROGRAM INPUT FILE FORMAT

PROGRAM INPUT FILE PARAMETERS

Card	Column	Code	Format	Explanation
1	1-40	TITLE1	40A1	Title with up to 40 characters. Default = blanks
2	1-40	TITLE2	40A1	Title with up to 40 characters. Default = blanks
3	1-80		1X	Header Card
4		MSYM	Free	If MSYM = 1 then symmetric case assumed. If MSYM = 2 then asymmetric case assumed. Default = 1
		MHS	Free	If MHS = 0 then geometry doesn't include horizontal strut. If MHS = 1 then geometry does include horizontal strut. Default = 0

		MNC	Free	If MNC = 0 then geometry doesn't include nacelle. If MNC = 1 then geometry does include nacelle. Default = 0
		MVT	Free	If MVT = 0 then geometry doesn't include vertical tail. If MVT = 1 then geometry does include vertical tail. Default = 0
		MHT	Free	If MHT = 0 then geometry doesn't include horizontal tail. If MHT = 1 then geometry does include horizontal tail. Default = 0
5	1-80		1X	Header Card
6		RPF	Free	Propfan radius. If MNC = 0 then RPF value is not used. If RPF $\leq$ 0.0 or MNC = 0 then no propfan is assumed. RPF = RDSK in Card 27 in input file "flowinp" for the global Euler analysis. Default = 0.0
		XPF	Free	X-axis coordinate of propfan center XPF value not used if no propfan is assumed. XPF = XDSK0 in Card 27 in input file "flowinp" for the global Euler analysis. Default = 0.0
		YPF	Free	Y-axis coordinate of propfan center. YPF value not used if no propfan is assumed. YPF = YDSK0 in Card 27 in input file "flowinp" for the global Euler analysis. Default = 0.0
		ZPF	Free	Z-axis coordinate of propfan center ZPF value not used if no propfan is assumed ZPF = ZDSK0 in Card 27 in input file "flowinp" for the global Euler analysis. Default = 0.0
7	1-80		1X	Header Card
8		FSMACH	Free	Free stream Mach number value. PROGRAM stops if FSMACH $\leq$ 0.0 Default = 0.0
		GAMMA	Free	Specific heat ratio. PROGRAM stops if GAMMA $\leq$ 0.0 Default = 1.4
9	1-80		1X	Header Card
10		NXCMX	Free	Number of x = constant plane cuts to be generated. If NXCMX = -1 then an x = constant plane cut is generated 5 grid locations beyond the body trailing edge. PROGRAM stops if NXCMX > 20 Default = -1

11	1-80		1X	Header Card
12		XCUT	Free	X value for each x = constant plane cut to be generated. XCUT not used if NXCMX ≤ 0 Default = 0.0
13	1-80		1X	Header Card
14		NRSL	Free	Number of streamlines to be read from input file. PROGRAM stops if NRSL > 250 Default = 0
		MWGSL	Free	If MWGSL = 0 then no wing streamlines will be generated. If MWGSL = 1 then MSYM * (2 + KCWING / 2) wing streamlines will be generated downstream (KCWING is the number of cells on the wing in the k direction). Default = 1
		MHSSL	Free	If MHSSL = 0 or MHS = 0 or MNC = 1 then no horizontal strut streamlines will be generated. If MHSSL = 1 and MHS = 1 and MNC = 0 then MSYM * 2 horizontal strut streamlines will be generated downstream. Default = 1
		MHTSL	Free	If MHTSL = 0 or MHT = 0 then no horizontal tail streamlines will be generated. If MHTSL = 1 and MHT = 1 then MSYM * 2 horizontal tail streamlines will be generated downstream. Default = 1
		MBDSL	Free	If MBDSL = 0 then no body streamlines will be generated. If MBDSL = 1 then MSYM * (1 + JCBODY / 2) body streamlines will be generated upstream and downstream (JCBODY is the number of cells on the body in the j direction). Default = 1

		MPFSS	Free	If MPFSS = 0 then no propfan streamsurfaces will be generated. If MPFSS = 1 then MSYM propfan streamsurfaces containing 12 streamlines each will be generated upstream and downstream. No propfan streamsurfaces will be generated if no propfan is assumed. Default = 1 Note: PROGRAM stops if the total number of streamlines is greater than 250. The total number of streamlines is NRSL + MWGSL * MSYM * (2 + KCWING / 2) + MHSSL * MSYM * 2 + MHTSL * MSYM * 2 + MBDSL * MSYM * 2 * (1 + JCBODY / 2) + MPFSS * MSYM * 2 * 12
15	1-80		1X	Header Card
16		CSLDIR	Free	Streamline direction flag for each streamline. If CSLDIR = -1.0 then streamline will be generated upstream. If CSLDIR = 1.0 then streamline will be generated downstream. Default = 1.0
		ISL	Free	Initial i index grid location for each streamline. Default = 0
		JSL	Free	Initial j index grid location for each streamline if MHT = 1 then both upper and lower surfaces of the horizontal tail are assigned a j index. Default = 0
		KSL	Free	Initial k index grid location for each streamline. If MNC = 1 then both inner and outer surfaces of the nacelle are assigned a k index. Default = 0
		NSYMSL	Free	Initial right or left side index for each streamline. If NSYMSL = 1 or MSYM = 1 then initial streamline location is on the right side. If NSYMSL = 2 and MSYM = 2 then initial streamline location is on the left side. Default = 1
		XSL1	Free	Initial x-coordinate value for each streamline location. Default = 0.0
		YSL1	Free	Initial y-coordinate value for each streamline location. Default = 0.0

		ZSL1	Free	Initial z-coordinate value for each streamline location. Default = 0.0 Note: The parameters CSLDIR, ISL, JSL, KSL, NSYMSL, XSL1, YSL1, and ZSL1 are not used if NRSL $\leq$ 0. Note: If ISL = 0 then XSL1, YSL1, and ZSL1 define the initial streamline location. If ISL > 0 then ISL, JSL, KSL, and NSYMSL define the initial streamline location.
17	1-80		1X	Header Card
18		NITMAX	Free	Maximum number of iterations used to determine streamline solution-value location and cell location. 2 $\leq$ NITMAX $\leq$ 50 Default = 20
		CNVTOL	Free	Relative convergence tolerance used to determine streamline solution-value location and cell location. PROGRAM stops if CNVTOL $\leq$ 0.0 PROGRAM stops if CNVTOL $\geq$ 0.5 Default = 0.0001
		CBTOL	Free	Relative tolerance used to check cell boundaries. PROGRAM stops if CBTOL $\leq$ 0.0 PROGRAM stops if CBTOL $\geq$ 0.5 Default = 0.001
		VTOL	Free	Velocity magnitude tolerance used to define stagnation points. Default = 0.0
		CSSINL	Free	Initial streamline integration step size coefficient. PROGRAM stops if CSSINL $\leq$ 0.0 PROGRAM stops if CSSINL $\geq$ 1.0 Default = 0.5

3.0 OUTPUT ANALYSIS

3.1 GRID GENERATION

BEGRID's primary output file is "eulergrid", which contains the coordinates of all grid points, and some additional data, in a binary format suitable for input to BBEAM2. Appendix section C.1 describes the structure of this file. BBEAM2 does not alter the grid, nor does it output the grid coordinates, therefore "eulergrid" must also be saved for later use with postprocessing programs.

The BEGRID programs record data pertinent to their computations by writing it to output files. These files, named "beg1.out", "beg2.out", "beg3.out", and "beg4.out", can be used to help track down errors in the grid generation procedure. They contain terse annotation to identify the data displayed. In particular, users must examine "beg4.out" to check for negative volume grid cells. Once the grid generation has been judged successful, these files should be deleted.

BEGRID2 produces three auxiliary files, "ktopvu", "kplane", and "surfacegrid." The file "ktopvu" holds grid point coordinates on the upper surface of the wing and wake. The file "kplane" contains grid coordinates on surfaces of constant K value previously selected by the user (input value 'kstations' in file "grd2inp"). "Surfacegrid" is a combination of individual files which contained grid coordinates on the following surfaces, in the order listed.

wing lower surface
wing upper surface and nacelle
strut (or conventional horizontal tail)
fuselage
vertical tail
high horizontal tail (if present)

"Ktopvu", "kplane", and "surfacegrid" are formatted as strings of coordinates, in the following manner.

line a. (number of points per string) (number of strings) 2F10.3
line b. (x1) (y1) (z1) (x2) (y2) (z2) 6F10.3
line c. (x3) (y3) (z3) (x4) (y4) (z4) 6F10.3

.
.
.

3.2 EULER

The Euler analysis program BBEAM2 produces a number of output files which are summarized in the table below. Sizes are approximate and assume a 240x36x32 grid.

filename	relative size in kbytes	type	description
fort.11	18000	binary	global flow solution. Also used as an input file for for restart runs.
bbeam.out	95	ascii	file which records program operation
fort.3	4	ascii	convergence history
fort.16	-	ascii	data on constant-x cut planes
fort.29	25	ascii	surface pressures on high horizontal tail lower surface
fort.30	25	ascii	surface pressures on high horizontal tail upper surface
fort.31	78	ascii	surface pressures on wing lower surface
fort.32	78	ascii	surface pressures on wing upper surface
fort.33	23	ascii	surface pressures on strutl lower surface
fort.34	23	ascii	surface pressures on strut upper surface
fort.35	112	ascii	surface pressures on fuselage lower surface
fort.36	112	ascii	surface pressures on fuselage upper surface
fort.37	27	ascii	surface pressures on vertical tail
fort.38	120	ascii	surface pressures on nacelle
fort.21	7700	binary	scratch
fort.22	3000	binary	scratch
fort.26	18000	binary	scratch
fort.40	18000	binary	scratch
fort.65	3200	direct	scratch
fort.66	9100	direct	scratch

fort.67 7100 direct scratch

For convenience, the Unix script which executes BBEAM2 processes the above files as follows:

fort.11 is renamed ffslnglb (flow field solution, global)
fort.3 is renamed bbeam.chist (bbeam convergence history)
fort.16 is renamed xplane_cuts (only produced if such cuts are requested)

fort. 35 36 31 32 33 34 38 37 29 30 are concatenated into one file named "surfpress", in that order.

fort. 21 22 26 40 65 66 67 are deleted. They are not needed once program BBEAM2 has finished execution.

Therefore the output files seen by the user are:

ffslnglb bbeam.out bbeam.chist surfpress [xplane_cuts]

3.2.1 FLOWFIELD IN BINARY FORMAT (ffslnglb)

At each grid point, BBEAM2 saves values for density, x momentum, y momentum, z momentum, total energy, and pressure. The grid points are grouped by blocks. Within each block, the I index varies most rapidly, followed by J, then K. A small amount of descriptive information is included at the end of the file, such as title and convergence data. Appendix section C.2 explains the structure of file "ffslnglb". Note that the grid input file "eulergrid" must also be saved to provide the grid point coordinates to postprocessing programs.

3.2.2 SURFACE PRESSURES (surfpress)

File "surfpress" contains lists of grid points on the aircraft surface, along with the corresponding pressure coefficient and Mach number. The file is arranged in network format, which is described in appendix C.

3.2.3 EXECUTION LOG FILE AND CONVERGENCE HISTORY

The file "bbeam.out" saves a description of the program's operation, while "bbeam.chist" records statistics on each iteration as the computation proceeds toward convergence. Both of these files contain annotation to identify the data displayed.

3.3 GRID EMBEDDING

Output Files from Embedded Grid Generation Program EMBGG

File	Purpose
sgemb	Surface grid written in networks.
fgemb	Computational grid for the embedded region

Output Files from Interpolation Program INTPP

File	Purpose

ffslnint	Provide boundary conditions and starting values for local embedded solution.

Output Files from Embedded Euler Flow Solver EMBFS

File	Purpose
tempcp	Surface pressure plot on all surfaces of the configuration.
fort.19	Velocity plot on the symmetry plane.
fort.20	Velocity plot at specified x/c.
fort.21	Mach number, velocity and pressure plot in the exhaust region, aft of exit plane.
fort.22	Velocity and pressure plot at the fan face.
ffslnemb	Restart file, rename as fort.30 for restart runs.
cvemb	Convergence history, a more detailed convergence history is given in embfs.out.

4.0 REFERENCES

1. Chen, H. C., and Yu., N. J., "Developing and Utilizing an Euler Computational Method for Predicting the Airfram/Propulsion Effects for an Aft-Mounted Turboprop Transport, Volume I: User Guide," NASA CR-181924, Vol. I, March 1991.

2. Samant, S. S., and Yu, N. J., "Flow Prediction for Propfan Engine Installation Effects on Transport Aircraft at Transonic Speeds," NASA CR-3954, January, 1986.

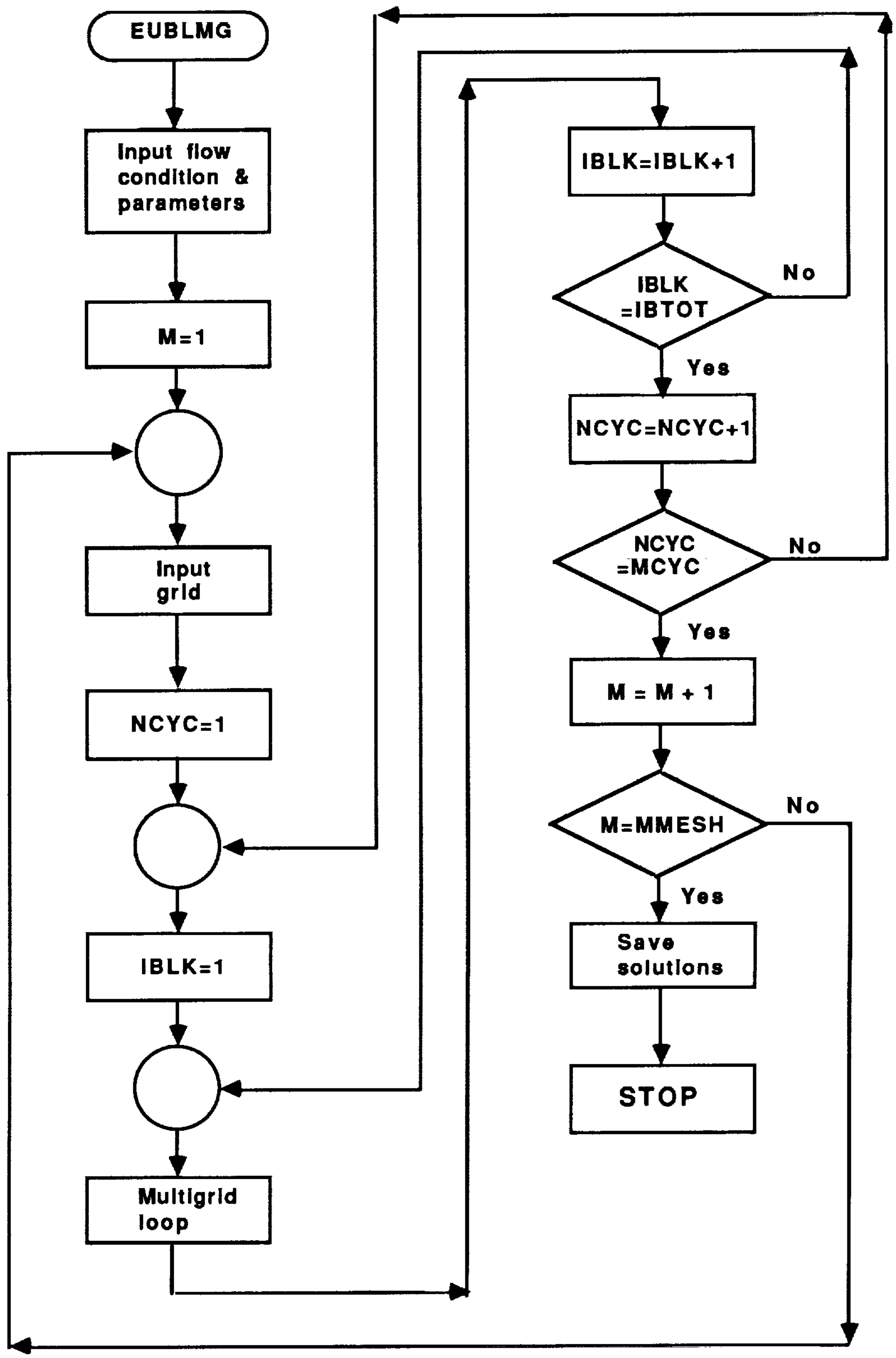
A.0 CONVERSION TO UNICOS ENVIRONMENT ON THE NAS CRAY-2

Many contemporary high speed computers use the Unix operating system, and in the near future practically all such machines will be Unix based. The PFE889 codes, developed under the Cray operating system (COS) on a Cray Xmp-24, can now be executed in the Unix environment on the Cray-2.

Porting these programs to Unix required only minor source code modification. Each code is written in fortran, and the changes simply eliminated reliance on some commonly accepted but nonstandard features of fortran input-output. External library procedures referenced by PFE889 were checked and found to be available under Unix, just as they had been under COS. During execution, PFE889 uses a considerable amount of disk space for temporary storage. On the Cray-2, the location used for this storage had to be explicitly chosen so as to remain within disk space allocations. No other Cray-2 specific coding changes were made, and in particular code optimization for the Cray-2 was not investigated.

The several programs of PFE889 are designed to be executed consecutively via a set of operating system commands. Under COS, these commands were grouped into a jobdeck, while under Unix they are known as a script. Porting PFE889 required implementing the logic of the COS jobdeck in the syntax of a Unix script. For the NAS Cray-2, this script has been further tailored to utilize the Network Queueing System, a batch processing facility available on many Unix systems.

B.0 GLOBAL EULER CODE FLOW CHART



In this flow chart the integer variable M in the outer-most loop controls the grid level in the successive mesh refinement process. M starts with a value one and is incrementted by one whenever the mesh is refined. The successive mesh refinement process will run up to a prespecified mesh level MMESH = FMESH defined by user input in page 19. The next loop is time-stepping loop with integer parameter NCYC. Time-stepping starts at NCYC = 1 and end at a prespecified number MCYC. The third loop is for controlling the multiblocking. The integer variable IBLK denotes the block number and total number of blocks is denoted by IBTOT. The inner most loop in this flow chart is the multigrid loop. The level of multigrid in this loop is defined by user input GMESH in page 20. The algorithm is similar for the embedded solver except that the latter is a single block code.

C.0 EXECUTION PROCEDURES UNDER THE NETWORK QUEUEING SYSTEM

The following Unix script files are used to execute portions of PFE889. These are typically submitted to the Network Queueing System, which is a batch method of execution available under several versions of Unix. They could also be run directly as background processes. To submit these files to NQS, use the command line % qsub script_filename .

C.1 GRID GENERATION (GLOBAL)

```
#@$-lt 499                      # NQS time request
#@$-lm 3mw                        # NQS memory request
#
cd /scratch/my_area/casexyz              # choose desired scratch directory as files are large
mv $HOME/datafiles/xyz.grd1inp ./grd1inp      # make datafiles available
mv $HOME/datafiles/xyz.grd2inp ./grd2inp
mv $HOME/datafiles/xyz.components ./components
#
$HOME/bin/begrid1 < grd1inp >& beg1.out       # begin executing BEGRID1
#
cat wing1 wing2 > wing                 # create file wing
rm wing1 wing2
#
echo " ******* done with BEGRID1 *******"
#
$HOME/bin/begrid2 < grd2inp >& beg2.out       # begin executing BEGRID2
#
rm fort.7 fort.9 fort.10 fort.11 fort.16      # delete unneeded files
rm fort.31 fort.32 wing nacelle fuslag       # and combine surface grids
cat wlower wupnac strut fulslag vtail hvtail > surfacegrid
rm  wlower wupnac strut fulslag vtail hvtail
#
echo " ******* done with BEGRID2 *******"
#
$HOME/bin/begrid3 < components >& beg3.out      # begin executing BEGRID3
#
echo " ******* done with BEGRID3 *******"
#
$HOME/bin/begrid4 < components >& beg4.out      # begin executing BEGRID4
#
echo " ******* done with BEGRID4 *******"
#
time                         # write time used in log file
```

C.2 EULER (GLOBAL)

```
#@$-lt 7199                        # NQS time request
#@$-lm 13mw                         # NQS memory request
#
cd /scratch/my_area/casexyz                  # choose desired directory
mv $HOME/datafiles/xyz.indata ./flowinp       # make datafile available
assign -a /scratch/my_area/eulergrid fort.14   # grid read from unit 14
#
$HOME/bin/bbeam2 < flowinp >& bbeam.out        # begin execution
#
mv fort.11 ffslnglb                    # rename solution file
mv fort.3  bbeam.chist                    # rename convergence history
mv fort.16 xplane_cuts                   # rename constant x cuts
rm  fort.17 fort.19 fort.20 fort.21 fort.22 \
   fort.26 fort.40 fort.65 fort.66 fort.67    # delete unneeded files
cat fort.35 fort.36 fort.31 fort.32 fort.33 \
   fort.34 fort.38 fort.37 fort.29 fort.30 > surfpress
rm  fort.35 fort.36 fort.31 fort.32 fort.33 \
   fort.34 fort.38 fort.37 fort.29 fort.30
#
time                             # write time used in log file
```

Note: For a restart run, make sure to move the most recent flow solution out of the working directory, then alias it to file fort.10. Delete or rename the intermediate output files before beginning execution. Remember that "flowinp" variable FSTART must be set to 1.0 for a restart run, and that the grid file "eulergrid" is still required.

```
cd /scratch/my_area/casexyz
mv ffslnglb /scratch/my_area/ffslnglb.1
assign -a /scratch/my_area/ffslnglb.1 fort.10
mv bbeam.out bbeam.out1
mv bbeam.chist bbeam.chist1
rm  fort.17 fort.19 fort.20 fort.21 fort.22 \
   fort.26 fort.40 fort.65 fort.66 fort.67
rm  fort.35 fort.36 fort.31 fort.32 fort.33 \
   fort.34 fort.38 fort.37 fort.29 fort.30
assign -a /scratch/my_area/eulergrid fort.14
$HOME/bin/bbeam2 < flowinp > bbeam.out
  .
  .
  .
```

C.3 GRID EMBEDDING

```
#
#
#@$-lt 99
#@$-lm 20mw
#
mv nac fort.1
mv str fort.2
#
#   update
#
echo "update embgg"
update -i embgg -c tmp
#
#   compilation
#
echo "compile"
cf -o tmpex tmp.f
#
#    execution
#
echo "execution"
tmpex < embginp > embgg.out
#
rm tmp.f tmpex
mv fort.1 nac
mv fort.2 str
mv fort.11 sgemb
mv fort.13 fgemb
#
#
# *** Interpolation -- step1
# *** Extract a reduced flowfield for interpolation
#
# prepare global grid and flow solution files
# for interpolation
# grid file     --> fort.10
# flow solution --> fort.30
#
mv eulergrid fort.10
mv ffslnglb fort.30
#
#   compilation
#
echo "compile interp step1"
cf -o tmpex1 intpp1.f
#
#   execution
#
echo "execution"
tmpex1 < intpinp > intpp1.out
#
mv FT20 GREDU
mv FT40 QREDU
rm tmpex1
mv fort.10 eulergrid
mv fort.30 ffslnglb
```

```
#
# *** Interpolation -- step2
# *** generate an embedded grid at cell center by averaging the vertecies
#
mv fgemb FT01
#
#   compilation
#
echo "compile interp step2"
cf -o tmpex2 intpp2.f
#
#   execution
#
echo "execution"
tmpex2 > intpp2.out
#
mv FT04 FLGDX
mv FT01 fgemb
rm tmpex2
#
# *** Interpolation -- step3
# *** Interpolation from the reduced grid to the cell-centered embedded grid
#
#   compilation
#
echo "compile interp step3"
cf77 -o tmpex3 intpp3.f
#
#   execution
#
echo "execution"
tmpex3 <<EOF > intpp3.out
GREDU
N
FLGDX
N
QREDU
QNEW
1
EOF
mv QNEW Q
rm tmpex3
#
# *** Interpolation -- step4
# *** Enrich the interpolated flowfield for embedded flow calculation
#
#   compilation
#
echo "compile interp step4"
cf -o tmpex4 intpp4.f
#
#   execution
#
echo "execution"
tmpex4 > intpp4.out
#
rm tmpex4
mv fort.2 ffslnint
```

```
#
# @@@@ embbed grid flow solution calculation @@@@
#
mv ffslnint fort.2
mv fgemb fort.11
#
# update
#
echo "update embbed flow solver"
update -i sembd1 -c embfs
#
#  compilation
#
echo "compile embbed flow solver"
cf -o embfs embfs.f
#
#  execution
#
echo  "execution"
embfs < embfinp > embfs.out
#
mv fort.3 cvemb
cat fort.31 fort.35 fort.36 fort.37 fort.38 > tempcp
# fort.32 -- nacelle center body surface pressure
# fort.33 -- nacelle fan inlet face sureface pressure
# fort.34 -- nacelle fan exhaust face surface pressure
# with domed nacelle fort.32, fort.33, fort.34 will not use
#
rm fort.31 fort.35 fort.36 fort.37 fort.38
mv fort.1 ffslnemb
rm embfs embfs.f FLGDX GREDU Q QREDU
#
#  clear up
#
```

C.4 STREAMLINE TRACING

```
#
#@$-lt 99
#@$-lm 20mw
#
# compilation and link
#
        echo "compile and link"
 cf -o nasae3p nasae3p.f
#
# input files: grid file -- fort.10
#          flow data -- fort.20
#
# output files: surface properties -- fort.91
#           constants X cuts  -- fort.92
#           streamlines output -- fort.93
# exec
nasae3p<<EOF
7D7 WING/BODY CASE AH
M = 0.7   ALPHA = 4.7   BETA = 0.0
MSYM, MHS, MNC, MVT, MHT
  1,  0,  0,  0,  0
 RPF,   XPF,   YPF,   ZPF
0.0, 1500.0, 279.0, 111.5
FSMACH, GAMMA
  0.7,  1.4
NCMX
 -1
XCUT
 0.0
NRSL, MWGSL, MHSSL, MHTSL, MBDSL, MPFSS
 0,   1,   0,   0,   0,   0
CSLDIR, ISL, JSL, KSL, NSYMSL,      XSL,      YSL,      ZSL

NITMAX, CNVTOL, CBTOL, VTOL, CSSINL
   20, 0.0001, 0.001,  0.0,   0.5
EOF
rm fort.30 fort.31 fort.32 fort.33 fort.34 fort.40 fort.41 fort.42
rm fort.43 fort.44 fort.45 fort.46 fort.47 fort.60
```

C.5 INCORE EULER

```
#
# INPUT : unit 10 -- grid file (binary)
#
# OUTPUT: unit 1  -- flow field restart file
#       unit 11 -- velocity vector plot file (GGP)
#       unit 21 -- convergent history file
#       unit 22 -- wing Cp plot file (GGP)
#       unit 23 -- surface properties plot file (GGP)
#
# SYNTAX for compilation
#
cf ineuler.f -o ineuler
#
# Execution
#
ineuler<<EOF
PROPFAN WING/BODY/NACELLE/DISK EULER ANALYSIS
NX     NY     NZ     MMESH   FCONT
64.0   8.0    12.0   1.0     0.0
NEND    NPRNT   NOUT   NTIM    IPRNT   LPRNT   SMOVPV
002.0   500.0   1.00   20.0    0.0     8.00    -2.20
CFL    BCW     Q FIL   VIS2    VIS4    H FACTOR SMOOP   BCB
-4.0   -1.0    1.0     2.0     2.0     0.25     -2.2    -1.0
FMACH   ALPHA
0.80    2.6
GRIDN   CC1    FMNAC
2.00    0.10   0.00
FNCUT
1.0
XCUT
 6.0
FMDSK    FIRDSK
0.0      10.0
EOF
```

D.0 EXAMPLE OF INPUT FILES

D.1 EXAMPLE OF INPUT FILE grd1inp

```
EXAMPLE GEOMETRY FOR AN NASA AFT MOUNTED PROPFAN AIRPLANE
FNX       FNY       FNZ
80.       36.       24.
FSPAN     FSB       FST       ZSPAN     FKTIPT
2.0       0.0       0.0       20.0      9.0
TNX       TNZ       NW1
240.      32.       16.
FHTAIL    FNACEL    FHVTAIL
1.0       1.0       1.0
FIFUS
31.0
XF        FN
   2.35000  19.00000
YP        ZP
   3.07651   0.00000
   3.02977   0.53423
      .
      .
  -3.02977   0.53423
  -3.07651   0.00000
      .
      .
XF        FN
 128.25000  19.00000
YP        ZP
   3.59791   0.00000
   3.57211   0.05238
      .
      .
  -0.14112   0.05238
  -0.16666   0.00000
      .
      .
FNS       SWEEP     DIHES
19.0      21.0      5.78
ZLE       XLE       YLE       CHORD     THICK     AL        FSEC
   7.24966  59.16176  -3.03092  20.13461   1.00000   0.00000   1.00000
YSYM      FNU       FNL
   0.00000  51.00000  51.00000
```

```
XPU         YPU
 0.0000000 0.0000000
 0.0016684 0.0034076
       .
       .
 0.9790025-0.1065637
 1.0001910-0.1134852
XPL         YPL
 0.0000000 0.0000000
 0.0070953-0.0145153
       .
       .
 0.9777517-0.1166166
 1.0000000-0.1152235
ZLE         XLE         YLE         CHORD       THICK       AL          FSEC
   8.55000  59.86908  -2.77667  19.45374   1.00000   0.00000   1.00000
YSYM        FNU         FNL
   0.00000  51.00000  51.00000
XPU         YPU
 0.0000000 0.0000000
 0.0015638 0.0057399
       .
       .
 0.9992211-0.0985668
 1.0001867-0.0988773
XPL         YPL
 0.0000000 0.0000000
 0.0004171-0.0057510
       .
       .
 0.9989980-0.1008684
 1.0000000-0.1008192
       .
       .
NASA PROPFAN NACELLE GEOMETRY
FNOUT       AA1C        BB1C        FKCUT       AA1S        BB1S
40.0        0.02        0.02        45.0        0.01        0.05
        62
        12
     96.8499985     10.6820002      5.0500002
     96.8499985     10.6820002      5.0500002
       .
       .
```

```
NASA PROPFAN STRUT GEOMETRY
FNOUT     AA1C     BB1C     FKCUT     AA1S     BB1S
65.0      0.03     0.05     9.0       0.10     0.10
        6
       52
    96.2194672      5.5776601      2.8724599
    96.2644424      5.5443201      2.9300599
      .
      .
NASA PROPFAN VERTICAL TAIL GEOMETRY
FNOUT     AA1C     BB1C     FKCUT     AA1S     BB1S
35.0      0.02     0.05     13.0      0.08     0.04
        5
       57
   105.3593903      0.0000000      6.4359198
   105.6121826      0.2810700      6.4038801
      .
      .
NASA PROPFAN HORIZONTAL TAIL GEOMETRY
FNOUT     AA1C     BB1C     FKCUT     AA1S     BB1S
65.0      0.01     0.05     17.0      0.0625   0.0625
       10
       57
   122.8178329      0.7001600     22.0200005
   122.8477173      0.6970500     22.0826302
      .
      .
```

D.2 EXAMPLE OF INPUT FILE grd2inp

```
VOLUME GRID GENERATION FOR AFT-MOUNTED PROPFAN AIRPLANE
FTEST     FLM       FNSAV     FMMRF     FPRINT
3.0       3.0       1.0       -1.0      2.0
FIT1      FIT2      FIT3      P1        P2        P3        TOL
50.0      100.0     100.0     1.70      1.70      1.70      0.001
FSYM      BODY      DYFACN    FJBODY
2.0       6.0       0.050     13.0
DYFAC     RFAC1     RFAC2     ZFAC      FREAD     FRD2      YFAC      YFAC2
0.020     5.0       2.0       3.0       12.0      8.0       1.0       2.0
FICKM     FISCL     FJSCL     FKSCL     FJNAC
1.00      1.00      1.00      1.00      7.0
FISCL2    FJSCL2    FISCL3    FJSCL3    FDISC     DDISC
1.00      1.00      0.90      0.90      1.00      1.0
CC1       CC2       CC3       CC4       CCZ       STRMIN    FIUBE
-1.0      2.0       1.0       2.25      2.00      1.20      1.00
NCUTS
1.00
KSTATIONS (15I5)
   01   00   00   00
XDISC     YDISC     ZDISC     XTNAC
115.0     5.05      10.682    118.3
FNAC      FIRD4     FPER      FSMOO     FKSTRUT   FKNACL
-1.0      4.0       0.0       -2.0      5.0       5.0
```

D.3 EXAMPLE OF INPUT FILE components

```
FTAIL     FUBE      HVTAIL
1.0       1.0       1.0
```

D.4.1 EXAMPLE OF INPUT FILE flowInp (FMESH = 1.0)

```
EULER ANALYSIS FOR NASA AFT-MOUNTED PROPFAN AIRPLANE
FNX       FNY       FNZ       FA        FMESH     FIDIM     FJDIM     FKDIM
240.0      36.0      32.0      1.0       1.0     241.0      13.0      17.0
FCYC      FPRNT     FTIM      GPRNT     HPRNT     GMESH     CFLFI
 400.0    2000.      1.0      -1.0     2000.0     1.0       0.00
FSTART    GINFIL    RTRMS0    FNCYBL    WNECK     SMESH     FTYPE     FTTAIL
  0.0      10.0      0.0      5000.0     1.0       3.0       1.0        1.0
CFLF      BC        QFIL      VIS2      VIS4      HFACTOR   GTYP      ALLM
 -5.0      -1.0      1.0       2.00      2.0       .25       0.0
C1        C2        C3        C4        C5        C6
 .2500     .166667   .375     0.5000    1.0000    0.0000
SMOOPI    SMOOPJ    SMOOPK
2.50      2.00      1.50
FITD0     FITUP     CFLC      HMC       FBC       FCOLL     FADD      VI
  1.0       0.0      -5.0      0.0       1.0       1.0       1.0       2.0
FMACH     ALPHA     ALYAW     FIRUN     RMOLD     ALOLD     ALYWOLD   CD0
 .8000     1.5000     0.0      -1.0      0.8000    1.5000    0.0       0.0
AREF      XREF      YREF      ZREF      CREF      SREF
396000.0   1339.0     0.0      190.8     327.8     327.8
FSCZ      CC1       CC2       FIYAW     FISTLF    FINCLF    FIPPLF    FMVTL
1.00      1.00      1.0        0.0       0.0       0.0       0.0       1.0
FTAIL     FIBODY    FITEBC    FMNAC     GRDN      FMDSK     XTENAC    WINGLET
 2.0      11.0      1.0        2.0       0.0       1.0      118.3      0.0
FMTYPE    FIRDSK
2.0       7.0
XDSK0     YDSK0     ZDSK0     RDSK
115.0     5.05      10.682    5.0
RDS       THRUST    FNORMAL   FSPAN     WORK
0.0       0.1232    0.        0.        0.
1.0       0.1232    0.        0.        0.
2.0       0.1232    0.        0.        0.
2.5       0.1232    0.        0.        0.
3.5       0.1232    0.        0.        0.
4.5       0.1232    0.        0.        0.
5.0       0.1232    0.        0.        0.
FNCUT     YWTR0     DYWTR     FNWTR
 0.0       540.0     -50.0     5.0
END OF CALCULATION
FNX       FNY       FNZ
 0.        0.        0.
```

D.4.2 EXAMPLE OF INPUT FILE flowinp (FMESH ≠ 1.0)

```
EULER ANALYSIS FOR NASA AFT-MOUNTED PROPFAN AIRPLANE
FNX       FNY       FNZ       FA        FMESH     FIDIM     FJDIM     FKDIM
 60.0       9.0       8.0       1.0       3.0      61.0       4.0       5.0
FCYC      FPRNT     FTIM      GPRNT     HPRNT     GMESH     CFLFI
 400.0    2000.       1.0      -1.0     2000.0      1.0       0.00
 400.0    2000.       1.0      -1.0     2000.0      2.0       0.00
 400.0    2000.       1.0      -1.0     2000.0      3.0       0.00
FSTART    GINFIL    RTRMS0    FNCYBL    WNECK     SMESH     FTYPE     FTTAIL
  0.0      10.0       0.0     5000.0      1.0       3.0       1.0        1.0
CFLF      BC        QFIL      VIS2      VIS4      HFACTOR   GTYP      ALLM
 -5.0      -1.0       1.0      2.00       2.0       .25       0.0
C1        C2        C3        C4        C5        C6
 .2500     .166667   .375     0.5000    1.0000    0.0000
SMOOPI    SMOOPJ    SMOOPK
2.50      2.00      1.50
FITD0     FITUP     CFLC      HMC       FBC       FCOLL     FADD      VI
  1.0       0.0      -5.0       0.0       1.0       1.0       1.0       2.0
FMACH     ALPHA     ALYAW     FIRUN     RMOLD     ALOLD     ALYWOLD   CD0
 .8000     1.5000     0.0      -1.0      0.8000    1.5000     0.0       0.0
AREF      XREF      YREF      ZREF      CREF      SREF
396000.0   1339.0     0.0      190.8     327.8     327.8
FSCZ      CC1       CC2       FIYAW     FISTLF     FINCLF   FIPPLF    FMVTL
1.00      1.00      1.0        0.0       0.0        0.0       0.0       1.0
FTAIL     FIBODY    FITEBC    FMNAC     GRDN      FMDSK     XTENAC    WINGLET
 2.0      11.0      1.0         2.0      0.0       1.0       118.3      0.0
FMTYPE    FIRDSK
2.0       7.0
XDSK0     YDSK0     ZDSK0     RDSK
115.0     5.05      10.682    5.0
RDS       THRUST    FNORMAL   FSPAN     WORK
0.0       0.1232    0.        0.        0.
1.0       0.1232    0.        0.        0.
2.0       0.1232    0.        0.        0.
2.5       0.1232    0.        0.        0.
3.5       0.1232    0.        0.        0.
4.5       0.1232    0.        0.        0.
5.0       0.1232    0.        0.        0.
FNCUT     YWTR0     DYWTR     FNWTR
 0.0       540.0     -50.0     5.0
END OF CALCULATION
FNX       FNY       FNZ
 0.        0.        0.
```

D.5 EXAMPLE OF INPUT FILE embgInp

```
FIMX       FJMX       FKMX       FNTYP      FSTYP
101.       21.        25.        0.0        0.0
FNAC       FSTR       FNACSI     FYZ        FKFULL
2.         2.          1.0       1.0        0.0
FMDSK      XDSK       YDSK       ZDSK       RDSK
1.0        115.00     5.05       10.682     5.00
FICU
5.
FIOCU(ICU)
1.0        21.0       61.0       73.0       85.0
FJCU
3.0
FJOCU(JCU)
1.0        13.0       21.0
FKCU
1.0
FKOCU(KCU)
1.0
DYFAC      YFAC       XFAC
0.015      1.5        2.0
FITK1      FITK2      FIT3D      TOL
 50.0       50.0       50.0      0.001
P1         P2         P3         FICTL      FJCTL      FKCTL
1.5        1.5        1.5        1.0        0.50       1.0
FKCUT
3.0
K-STATION GRID
1.         13.        25.
FJCUT
2.
J-STATION GRID
9.0        21.0
FICUT
4.
I-STATION GRID
2.         21.0       61.0       85.0
```

D.6 EXAMPLE OF INPUT FILE Intplnp

```
FNX        FNY        FNZ        FA         FMESH      FIDIM      FJDIM      FKDIM
60.0       9.0        8.0        0.0        0.0        61.0       4.0        5.0
```

D.7.1 EXAMPLE OF INPUT FILE embfinp (FMESH = 1.0)

```
NASA AFT-MOUNTED NACELLE CONFIGURATION
NX         NY         NZ         MMESH      FCONT      FAGPS
100.0        20.0      24.0      1.0        1.0        1.0
NEND       NPRNT      NOUT       NTIM       IPRNT      LPRNT      HMMH       PSMOOV
500.0      9000.0      2.0        5.0       -1.0         4.0      0.20       0.0
CFL        BC         Q FIL      VIS 2      VIS 4
-2.5        0.0        0.         1.00       0.50
FMACH      ALPHA      CD0        YAW        FIBCW      FIGUS      FJSCAL
0.800      1.50       0.01       0.0        1.0        0.0         2.0
FMIN       Q/QINF     P/PINF     RQ/RQINF   FMOUT      PT/PINF    TT/TINF
1.         .000       0.         0.         1.         1.8361     2.8270
AINFTY     REFA       FKSYM      FDAFT      FIFLO      FKSMLR     FNBC       BCST
4566.7      219600.    0.0        1.0        5.0        0.0        1.0        0.0
FIXYUV     FINET
 0.0        7.
FIXYM      FIDEL
 0.0       25.
FIYZVW     FINET2     XOCS       DXOC
 0.0       7.         0.5        0.5
FIYZFF
 0.0
FIBLC      FINBL      FNBCFX     C1
 0.0        0.0        0.0        0.0
FMDSK      RPM        FNB        CINF       FMRF1
2.0        1000.0     8.0        1100.0     0.7
XDSK0      YDSK0      ZDSK0      RDSK
115.0      5.05       10.682     5.0
FIRDSK     PSTAT      TTCHK
7.0        3.458      0.0
RDIN       PTIN(PFX)  TTIN(PFY)  SWIN(PFZ)
0.0        0.1232     0.         0.
1.0        0.1232     0.         0.
2.0        0.1232     0.         0.
2.5        0.1232     0.         0.
3.5        0.1232     0.         0.
4.5        0.1232     0.         0.
5.0        0.1232     0.         0.
```

D.7.2 EXAMPLE OF INPUT FILE embfinp (FMESH ≠ 1.0)

```
NASA AFT-MOUNTED NACELLE CONFIGURATION
FNX       FNY       FNZ       FMESH     FCONT     FAGPS
 50.0       10.0     12.0     2.0       1.0       1.0
FEND      FPRNT     FOUT      FTIM      GPRNT     HPRNT     HMMH      PSMOOV
500.0     9000.0     2.0       5.0      -1.0        2.0     0.20      0.0
500.0     9000.0     2.0       5.0      -1.0        4.0     0.20      0.0
CFL       BC        QFIL      VIS2      VIS4
-2.5       0.0       0.        1.00      0.50
FMACH     ALPHA     CD0       YAW       FIBCW     FIGUS     FJSCAL
0.800     1.50      0.01      0.0       1.0       0.0        2.0
FMIN      QIN       PIN       QIN       FMOUT     PSTGO     TSTGO
1.        .000      0.        0.        1.        1.8361    2.8270
AINFTY    REFA      FKSYM     FDAFT     FIFLO     FKSMLR    FNBC      BCST
4566.7     219600.   0.0       1.0       5.0       0.0       1.0       0.0
FIXYUV    FINET
 0.0       7.
FIXYM     FIDEL
 0.0      25.
FIYZVW    FINET2    XOCS      DXOC
 0.0      7.        0.5       0.5
FIYZFF
 0.0
FIBLC     FINBL     FNBCFX    C1
 0.0       0.0       0.0       0.0
FMDSK     RPM       FNB       CINF      FMRF1
2.0       1000.0    8.0       1100.0    0.7
XDSK0     YDSK0     ZDSK0     RDSK
115.0     5.05      10.682    5.0
FIRDSK    PSTAT     TTCHK
7.0       3.458     0.0
RDIN      PTIN(PFX) TTIN(PFY) SWIN(PFZ)
0.0       0.1232    0.        0.
1.0       0.1232    0.        0.
2.0       0.1232    0.        0.
2.5       0.1232    0.        0.
3.5       0.1232    0.        0.
4.5       0.1232    0.        0.
5.0       0.1232    0.        0.
```

E.0 FILE FORMATS

E.1 GRID FILE eulergrid

The file "eulergrid", the unformatted (binary) grid file produced by BEGRID and read by BBEAM2, contains grid point coordinates arranged in a sequence of constant K-index surfaces. Each surface is written as a sequence of lines of constant J-index. For example, the fortran write statement which outputs the x coordinate of points on a specific K-index sheet is:

```
write(n) ((x(i,j,kval),i=1,imax),j=1,jmax)
```

The specific content of each record of "eulergrid" is:

Record	Contents
1	22 control variable values in integer format

Code	Explanation
IMX	Total number of grid points in I-direction
JMX	Total number of grid points in J-direction
KMX	Total number of grid points in K-direction
NB	Total number of grid points in I-direction on the fuselage
KTIP	K-index for the wing-tip station
ITE2	I-index at wing upper surface trailing edge
ITL2	I-index along the crown line of the fuselage at the tip of the tail cone
JBY	Number of grid points normal to the wing on the fuselage
KTIPT	K-index at the aft-mounted strut/nacelle junction
ITLT	I-index at strut lower surface trailing edge
ILELT	I-index at strut lower surface leading edge
ILEUT	I-index at strut upper surface leading edge
ITUT	I-index at strut upper surface trailing edge
JNAC	Number of grid points normal to the strut on the nacelle
ILELN	I-index at nacelle lower surface leading edge
ILEUN	I-index at nacelle upper surface leading edge
IVTLE	I-index at vertical tail leading edge
IVTTE	I-index at vertical tail trailing edge
JVTIP	Number of grid points in J-direction on the vertical tail
KTIPHT	K-index at the tip of the high horizontal tail
ILEHT	I-index at high horizontal tail leading edge
ITEHT	I-index at high horizontal tail traili/ng edge

Record	Contents
2	x coordinates of the k=1 grid sheet
3	y coordinates of the k=1 grid sheet
4	z coordinates of the k=1 grid sheet
.	
.	
.	
3*(kmax-1)+2	x coordinates of the k=kmax grid sheet
3*(kmax-1)+3	y coordinates of the k=kmax grid sheet
3*(kmax-1)+4	z coordinates of the k=kmax grid sheet

If an aft nacelle is present, then the next three records contain coordinates of grid points which lie on the outboard half of that nacelle and plume surface. They're ordered the same way as are the points on constant k-index surfaces.

Note: let b = 3*(kmax-1)+4

Record Contents

b x coordinates of nacelle outboard surface
b+2 y coordinates of nacelle outboard surface
b+3 z coordinates of nacelle outboard surface

If a high horizontal tail, also known as a t-tail, is present, then the next three records give the coordinates of the constant J-index surface containing the top half of the t-tail surface. These records are written out in the following manner:

```
write(n) ((x(i,k),i=1,imax),k=1,ktipt)
```

<u>Record</u> <u>Contents</u>

b+4 x coordinates of the extra t-tail surface
b+5 y coordinates of the extra t-tail surface
b+6 z coordinates of the extra t-tail surface

E.2 FLOW SOLUTION FILE ffslnglb

The flow solution file "ffslnglb" contains six flow variables, namely density, x momentum, y momentum, z momentum, total energy, and pressure, written consecutively for each grid point on a block by block basis. In terms of a fortran write statement, this can be expressed:

```
 do 1  kblock = 1, (number of blocks in k direction)
 do 1  jblock = 1, (number of blocks in j direction)
 do 1  iblock = 1, (number of blocks in i direction)
1 write(iu) ((((w(m,i,j,k),m=1,6),i=1,ibx),j=1,jbx),k=1,kbx)
```

where ibx,jbx,kbx are the maximum block dimensions

For nonzero yaw angles, the above information is repeated for each side of the configuration. Following this flow data, "ffslnglb" contains a small amount of convergence information.

This file is unformatted, that is, it contains binary data. Currently, the number of blocks in i direction is equal to one.

E.3 SURFACE PRESSURE FILE surfpress

A surface pressure file begins with control cards describing the data line contents and format, number of points per list, etcetera. An example is shown below.

```
(i5,7f10.4)
*dupt
$euler analysis for a complete airplane
$configuration
$     113 13 1  41  25 1  33  9 1  53  14 1  21  4 1  27  13 1  19  17 1
*dup
+ 1i
+ 2x
+ 3y
+ 4z
+ 5xoc
+ 6cp
+ 7mach
+ 8yoc
frl1   <-  title for the following data, grouped using first three letters
```

```
 i    x      y      z    xoc     cp    mach    yoc
 1  59.1618  -3.0309  7.2882  0.0000  0.5070  0.5615  0.0000
 2  59.1672  -3.1045  7.2440  0.0000  0.7314  0.4363  0.0000
 3  59.2046  -3.1783  7.2166  0.0000  1.0990  0.1630  0.0000
        .
        .
        .
111  127.0796  1.7139  0.5584  0.0000  0.1303  0.7301  0.0000
112  127.8858  1.7128  0.3929  0.0000  0.1649  0.7152  0.0000
113  128.4354  1.7126  0.2393  0.0000  0.2213  0.6879  0.0000
*eof  <- end of this list
frl2  <- second list in `frl' group
 1  58.8168  -3.0339  7.0803  0.0000  0.4361  0.5953  0.0000
 2  58.8303  -3.1216  7.0241  0.0000  0.4680  0.5808  0.0000
 3  58.8648  -3.2099  7.0061  0.0000  0.4884  0.5713  0.0000
        .
        .
        .
```